Engineering Materials and Design

★ *The Magazine for Engineering Designers*

A HEYWOOD PUBLICATION

Vol. 2 No. 12 December 1959

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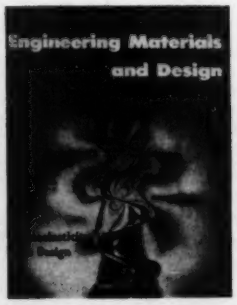

COVER shows the stress patterns that are "visible" in the photoelastic method of experimental stress analysis. This example was photographed at University College, London. (See article on page 600.)

Published monthly by HEYWOOD & COMPANY LTD., Drury House, Russell Street, London, W.C.2 (Tel.: TEMple Bar 3422), on the 15th of the preceding month. Annual subscription 35s. sterling per annum ($5.25, U.S.A. and Canada) throughout the world. Single copies to order from all newsagents and bookstalls, 2s. 6d. each (by post from the publishers, 3s. 0d. each). BRANCH OFFICES: Royal Buildings, 2 Mosley Street, Manchester, 2, Tel.: Central 9935; Bayliss House, Hurst Street, Birmingham, Tel.: Midland 5786; 52 St. Enoch Square, Glasgow, Tel.: City 3492; 527 Madison Avenue, New York 22, N.Y., Tel.: Plaza 9-1171.

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ISSUE AT A GLANCE

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LA PHOTOÉLASTICITÉ AU SERVICE DU CONSTRUCTEUR

par J. R. Dixon

L'auteur décrit le role actuel de la photoélasticité dans l'analyse des efforts. Pour demontrer l'application de la photoélasticité aux problèmes specifiques, il donne également des exemples des travaux effectues sur (1) des échancrures carrées aux coins arrondis, (2) des pignons d'entrée pour boites d'engrenages, (3) des dents d'arrêt, (4) un arbre intermédiaire pour un système d'engrenages, ainsi que sur le cintrage experimental des goupilles et le forage des fentes.

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REVUE DES ÉLÉMENTS DE CHAUFFAGE ÉLECTRIQUE

par W. R. Eades

L'auteur décrit les alliages métalliques et autres matériaux employés dans des éléments de chauffage. Il discute ensuite les types normaux d'éléments disponibles en indiquant leurs meilleures applications. Il donne aussi des calculations de puissance réelle et des details de dessins d'éléments simples à partir des matériaux de base.

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RECHERCHES SUR LES MATÉRIAUX POUR LA ROYAL NAVY

Le role est decrit du Admiralty Materials Laboratory et du Central Dockyard Laboratory dans la mise à point et les éssais des matériaux pour l'emploi de la Royal Navy. L'auteur indique quelques travaux effectués et la contribution de ces études aux connaissances techniques au Royaume-Uni.

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L'APPLICATION DES MÉTAUX RAREMENT UTILISES POUR DES BUTS SPECIAUX

par J. P. Denny et L. F. Kendall

L'article examine la disponibilité, les coûts relatifs, les propriétés, la fabrication et les applications de sept metaux rarement utilisés dans la construction mécanique et qui peuvent servir pour des buts speciaux : le zirconium, le hafnium, le vanadium, le niobium, le tantale, le chrome et le rhenium.

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MATÉRIAUX UTILISÉS POUR LA PROTECTION CONTRE LES INCENDIES

par C. R. Webb

La nécessité de proteger l'équipement mécanique contre les dégâts causés par les incendies ont crée l' ntérêt actuel pour les ignifuges. L'article décrit les principes applicables au choix des matériaux pour la protection des coffres-forts et d'autres recipients ninflammables.

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DES INNOVATIONS DANS LE DOMAINE DE LA CONSTRUCTION

1. Servo-frein hydraulique avec tyuauterie d'admission à vide.
2. Tête porte-fraise à copier à construction coaxiale.
3. Flambeau à braser 2,000° C, avec préchauffage d'air et des gaz.
4. Barre de torsion et de tirage combinée pour les suspensions de remorques.

Kurzreferate

DIE FOTOELASTIZITÄT IM DIENSTE DES KONSTRUKTEURS

von J. R. Dixon

Die heutige Rolle der Fotoelastizität in der Druckanalyse wird erklärt. Um die Anwendungen der Fotoelastizität an spezifische Probleme zu erläutern, wird eine Reihe von durchgeführten Arbeiten beschrieben, namlich an 1) Viereckausschnitten mit abgerundeten Ecken, 2) Eingangszapfen für Getriebekasten, 3) Sperrzähnen, 4) einer Getriebezwischenwelle, sowie an experimentellen Stiftbiegungen und Ritzenausbohrungen.

ÜBERSICHT VON ELEKTRISCHEN HEIZELEMENTEN

von W. R. Eades

Verfasser beschreibt die metallischen Legierungen und andere in Heizelementen verwendete Materialien. Die heute verfügbaren Normtypen von Elementen werden einzeln besprochen und ihre Optimalanwendungen werden angegeben. Wattleistungsberechnungen und Einzelheiten der einfachen Elementkonstruktion aus Grundmaterialien werden ebenfalls angeführt.

MATERIALFORSCHUNG FÜR DIE ROYAL NAVY

Die Rolle des Admiralty Materials Laboratory und des Central Dockyard Laboratory in der Ausarbeitung und Prüfung von Materialien für den Gebrauch der Royal Navy wird erläutert. Ebenfalls beschrieben werden einige der durchgeführten Untersuchungen und der Beitrag dieser Arbeiten zum heutigen Stand der technischen Kenntnisse in England.

DIE ANWENDUNG WENIG BENUTZTER METALLE FÜR SONDERZWECKE

von J. P. Denny und L. F. Kendall

Die Verfügbarkeit, Relativkosten, Eigenschaften, Herstellung und Anwendung von sieben wenig benutzten technischen Metallen, die für Sonderzwecke von Wert sein können, nämlich Zirkon, Hafnium, Vanadium, Niobium, Tantal, Chrom und Rhenium, werden untersucht.

MATERIALIEN FÜR DIE BRANDVERHINDERUNG

von C. R. Webb

Die Notwendigkeit, technische Anlagen von brandverursachten Beschädigungen zu schützen, hat neuerdings ein Interesse für feuerbeständige Materialien erzeugt. Die Grundsätze der Auswahl von Materialien für die Isolierung von Geldschränken und anderen feuerbeständigen Behältern werden beschrieben.

NEUERUNGEN IN DER KONSTRUKTION

1. Hydraulische Servobremse mit Verwendung einer Vakuumeinströmleitung.
2. Kopierfräskopf in koaxialier Ausführung.
3. 2,000° C. Lötfackel mit Luft- und Gasvorwärmung.
4. Kombinierter Drill- und Zugstab in der Aufhängung von Anhängewagen.

Резюме

ФОТОЗЛАСТИЧНОСТЬ ПРИХОДИТ В ПОМОЩЬ КОНСТРУКТОРАМ

Дж. Р. Дикеон

В статье указывается на роль фотоэластичности в анализе напряжений. С тем, чтобы выявить применимость фотоэластичности к определенным задачам, приводится ряд примеров работ, проведенных на : 1) квадратном вырезе с округлыми углами, 2) подачной шестерне коробки скоростей, 3) упорных зубьях, 4) промежуточном вале коробки скоростей, а также в связи с опытным сгибанием штифтов и сверлением щелей.

ОБЗОР ЭЛЕКТРИЧЕСКИХ НАГРЕВАТЕЛЬНЫХ ЭЛЕМЕНТОВ

У. Р. Идс

Автор описывает металлические сплавы и другие материалы, употребляемые в нагревательных элементах. Затем обсуждается каждый из существующих стандартных типов элементов с указанием оптимального их применения. Даются расчеты нагрузок в ваттах и подробности конструкции простых элементов из основных материалов.

ИССЛЕДОВАТЕЛЬСКИЕ РАБОТЫ ПО МАТЕРИАЛАМ ДЛЯ КОРОЛЕВСКОГО ВОЕННОФЛОТА

В статье описывается роль Адмиралтейской Лаборатории по Материалам и Центральной Лаборатории Адмиралтейских Доков в разработке и испытании материалов для употребления Королевским Военнофлотом. Также описываются некоторые исследования, проведенные этими лабораториями, и технические улучшения, достигнутые в результате этих работ.

РЕДКО УПОТРЕБЛЯЕМЫЕ МЕТАЛЛЫ ДЛЯ СПЕЦИАЛЬНЫХ ЦЕЛЕЙ

Дж. П. Денни и Л. Ф. Кендалл

В статье обсуждается доступность, относительная стоимость, свойства, изготовление и применение семи редко употребляемых технических металлов, которые могут быть полезными для специальных целей — циркония, гафния, ванадия, ниобия, тантала, хрома и рения.

МАТЕРИАЛЫ ДЛЯ ПРЕДОТВРАЩЕНИЯ ПОЖАРОВ

Ч. Р. Уебб

Необходимость защиты технического оборудования от повреждений, вызванных пожарами, создала повышенный интерес в несгораемых материалах. Описываются принципы выбора материалов для изоляции сейфов и других несгораемых хранилищ.

КОНСТРУКЦИОННЫЕ НОВОВВЕДЕНИЯ

1. Гидравлический сервотормоз с вакуумным всасывающим патрубком.
2. Копировально-фрезерная головка соосной конструкции.
3. Брезинг-горелка на 2,000° С. с воздухо- и газоподогревом.
4. Комбинированный торционный и буксирный стержень для подвески прицепных тележек.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Improved P.T.F.E.

FLUON AND TEFLON are trade names for polytetrafluoroethylene which has been available for over ten years. Its outstanding properties are high softening temperature and almost perfect resistance to chemical attack, but these very facts have made it a difficult material to process. The material is supplied in the form of granules which must first be pressed together at room temperature and finally sintered at approx. 360 deg. C. The pressing operation is extremely critical because too little pressure leaves voids, whereas too much pressure causes cracks which cannot be sealed by subsequent heating, in either case giving a porous product. For extrusion of pipe linings in particular the process was never really perfected and the results were not reliable. In order to ensure freedom from porosity considerable thicknesses of p.t.f.e. were used, but in addition to the high cost other difficulties arose in production.

Mr. T. R. Thierry, of the Resistoflex Corp. of New Jersey, has recently been touring Britain with news of a new form of p.t.f.e. (Teflon 6) which is basically the same chemical material but in a specially fine form and having a special structure which, it is said, now makes it possible to produce thin tubes consistently without danger of cracking or porosity. BTR Industries Ltd. are licensed to operate the new process in the U.K. and hope shortly to be producing a full range of products.

The new material is slightly more dense than the earlier forms of p.t.f.e. and it is claimed to have considerably better tensile strength, electrical breakdown strength and elongation. In the U.S.A. it is being widely used for coating and lining chemical equipment and for many engineering parts subject to extreme corrosion. In many of these applications it is said to be showing economic advantages, for instance where it is used for lining steel to replace Monel, tantalum and stainless steel. It can also be used for coating electrical conductors to give a high temperature "enamel." An important application is stated to be for bellows which can now be moulded direct instead of being cut from solid bar. It is claimed that the new type of manufacture improves the flexing life for a given design by a factor of twenty times.

Water as Paint Solvent

THE FIRE AND TOXICITY HAZARDS of using conventional paint and varnish solvents have been real problems in industry, but there is now available a series of water soluble resins which can be used for the manufacture of stoving enamels. As long ago as 1953 these resins were marketed by Reichhold, Hamburg, after developments by Dr. H. Hönel of Vienna. They are now available in this country from Cray Valley Products Ltd.

Apart from the obvious economic advantages of replacing expensive organic solvents by water, there are numerous subsidiary advantages such as reduced insurance and equipment costs (no flameproof electrical gear is needed) and spray rooms can be washed down with water.

Paint on phenolic- and melamine-base resins can be formulated for many engineering applications and the well-known Swedish car, SAAB, has been finished using a water soluble primer followed by a conventional topcoat. A practical advantage of water soluble paint is found in the finishing of vehicle doors which are normally sprayed only on the outside, but allowing corrosion to proceed from within.

The use of water soluble paints allows dip coating to be applied very cheaply so that the whole door can be immersed in the paint which coats all surfaces, inside and out. The coating of petrol tanks inside has always been difficult owing to the tendency for organic solvents to wash off the coating during stoving, but water soluble paint is said to eliminate this problem. Many other applications are being tried out at the present time, but already it appears that this is one of the most important developments in product finishing for many years.

Developments in Electron Microscopy

IN THE LAST FEW YEARS revolutionary developments have taken place in the application of the electron microscope to the study of metals. Instead of replicas being prepared, metals in the form of thin films can now be examined directly by transmission, opening up immense possibilities for obtaining information. It is now possible, for example, to see directly dislocations and their movements and interactions; the early stages of precipitation can be followed in much greater detail than was possible previously, and the role of vacancies and dislocations in precipitation reactions is being clarified. Recrystallisation, phase transformations by shear, order-disorder reactions and radiation damage are further topics under investigation with the aid of these powerful methods. Recent achievements in this field were under discussion at a recent one-day symposium arranged by the metal physics committee of the Institute of Metals, when speakers came from Cambridge University, the Battelle Memorial Institute in Geneva, and the Max Planck Institute in Dusseldorf.

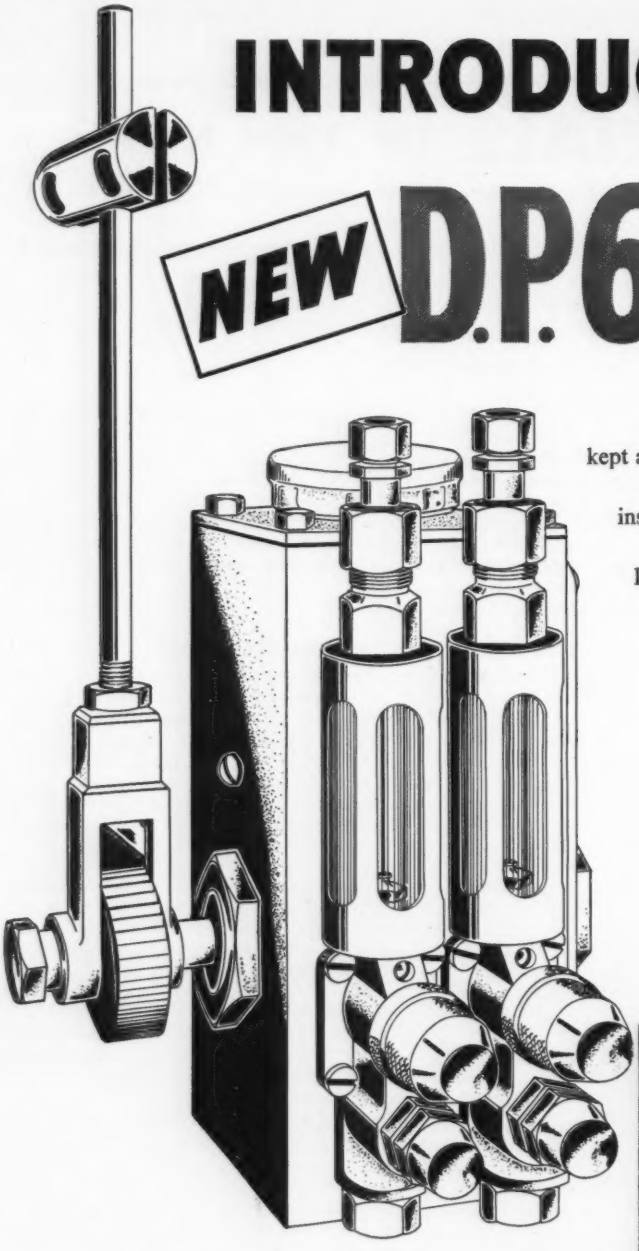
Nickel for Valve Cathodes

ONE OF THE MANY metallurgical problems in the manufacture of electronic valves is the control of nickel purity, particularly the material used for cathodes. Many impurities must be kept to the lowest possible amount, but a controlled impurity level of some important elements such as carbon, magnesium, manganese, silicon and titanium is essential for the correct activation of the cathode. In the past, attempts to produce a high purity by the usual hot melting techniques have met with only partial success and the valve engineer has always been looking for better control. By powder metallurgy techniques it is possible to provide a vastly superior product, but the costs of production do not warrant the full-scale use of the nickel produced in this way.

Vacuum melting may be a practical answer to the supply of a purer nickel but at a cost which makes it attractive to the valve industry.

A new material known as N 132 has been announced by the Radio Corp. of America; it is said that the maximum level of such contaminants as cobalt, copper, iron and sulphur has been greatly reduced but the proportion of the useful impurities has been strictly controlled. This step contributes directly to improved quality and reliability of valves by providing more uniform performance and—a big worry for the valve makers—uniformity of batches. British nickel suppliers are already examining this process, which may prove to be a better commercial proposition than powder metallurgy for the production of other high purity metals.

INTRODUCING THE NEW D.P.60 MECHANICAL LUBRICATOR



During the last 60 years, Wakefield lubricators have kept abreast of the changing needs of industry. The DP 60 represents the experience of these years. It is an instrument of precision for feeding oil against pressures up to 1,000 p.s.i. It can be operated by the plant it lubricates on reciprocating or rotating drive. The flow of oil is automatically controlled by the 'start-up and cut-off' of the machine. Efficient lubrication is combined with economy in oil consumption.

ADVANTAGES OF THE DP 60

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Up to 32 feeds can be fitted.

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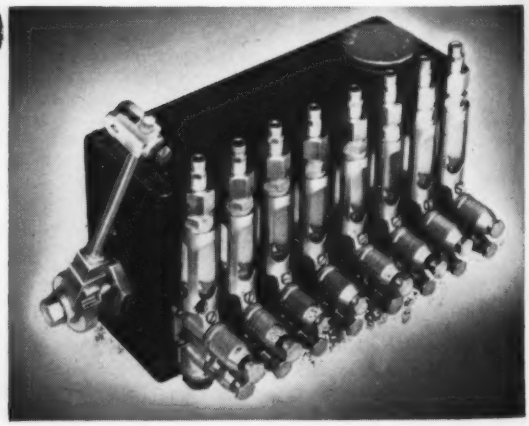
Built-in perspex oil gauge on the oil reservoir.



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INDUSTRIAL LUBRICATORS

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To Dept. PD Wakefield-Dick Industrial Oils Ltd.
Castrol House, Marylebone Road, London, N.W.1

NAME.....

ADDRESS.....

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EM

PICTURE NEWS

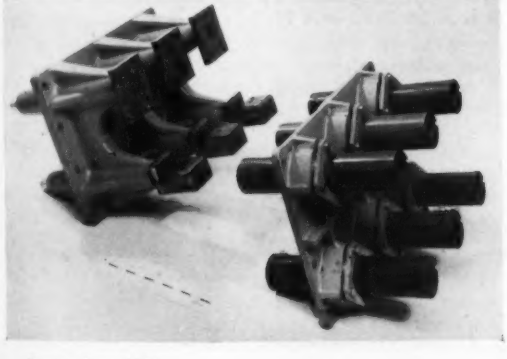
IN THE WORLD OF MATERIALS & DESIGN

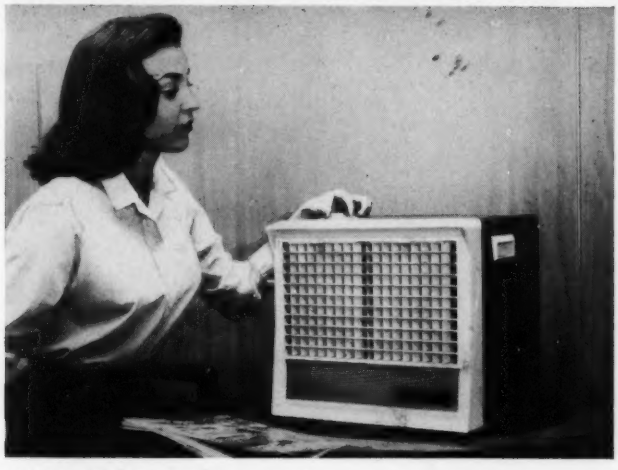
HYDROFOILS IN U.S.S.R.

First of several to be introduced on Moscow's waterways, this hydrofoil motorship is already in service and is claimed to be able to reach a speed of 45 m.p.h. It is made by the Krasnoye Sormovo works at Gorky, where a still larger version with a cruising speed of 60 m.p.h. is planned.

LEAK DETECTOR

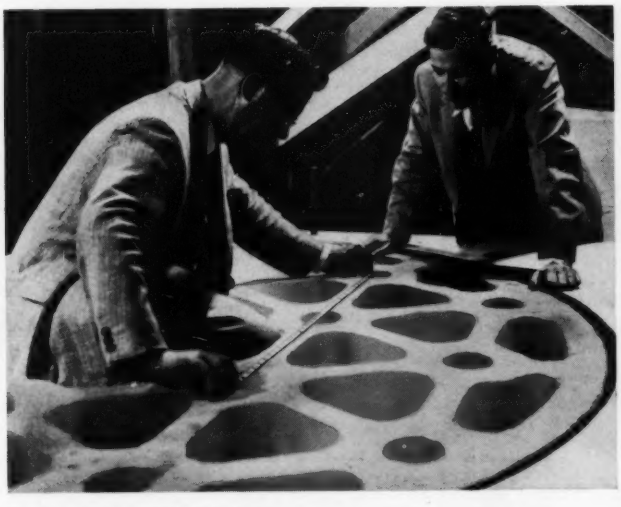
This leak detector was shown at the recent open day of the Ministry of Supply electrical inspection directorate. Shown here used for checking packaging film, it also has many practical applications in engineering. If a leak is suspected, a sensitive gas is introduced on the pressure side of the barrier, and a buzzer is set off as the probe passes over the leak point.





PLASTICS-COATED STEEL

Effective use of plastics-coated steel by a U.S. manufacturer gives this portable heating-cooling unit a durable and attractive finish. The cabinet itself is made from steel coated with vinyl supplied by B. F. Goodrich Chemical Co. Several British manufacturers are now producing plastics-coated steel for similar applications.



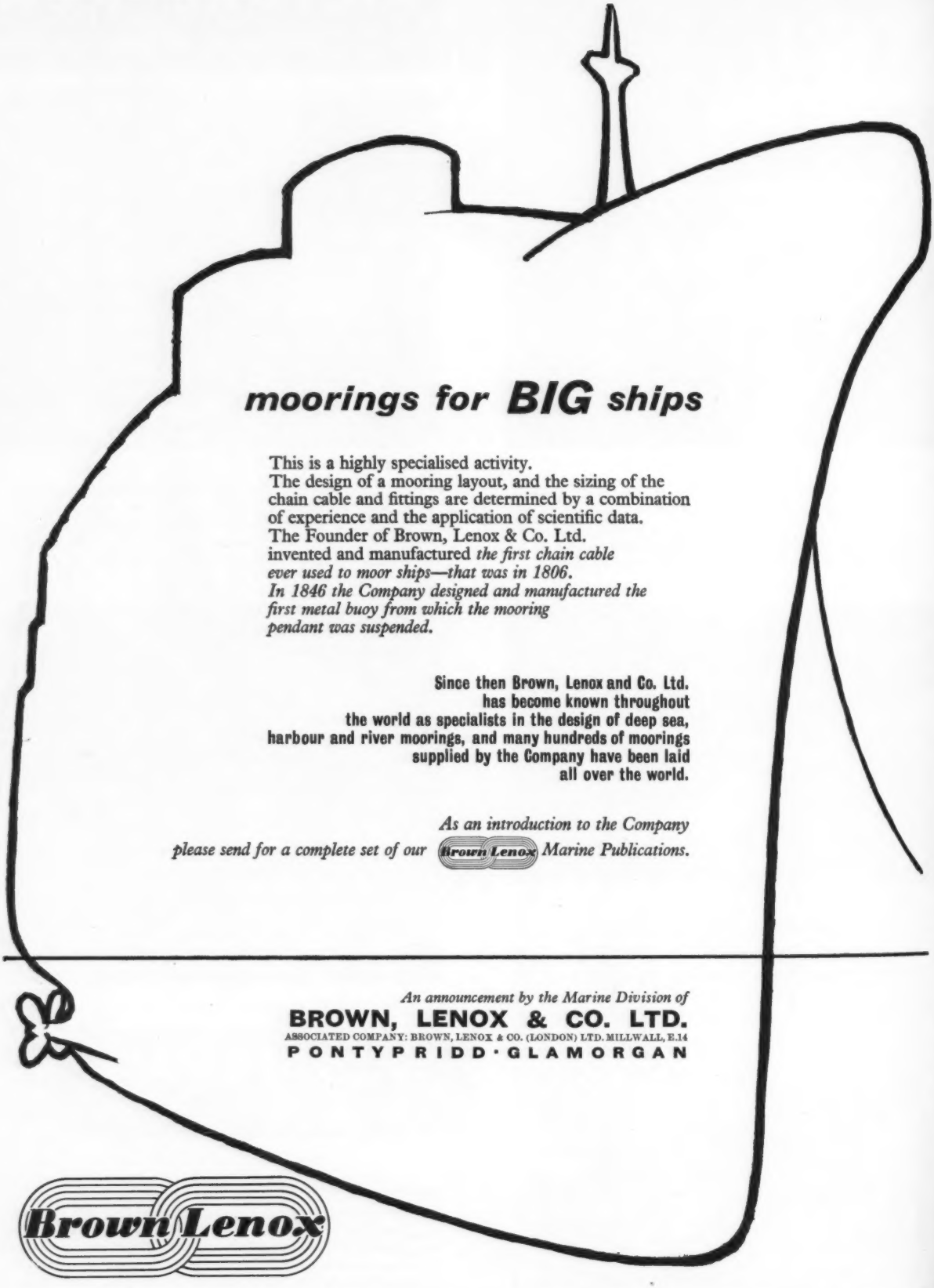
GIANT GLASS HONEYCOMB

This giant-size weight-saving honeycomb is a mirror blank for an 84-in. telescope at the Kitt Peak observatory in Arizona. It is claimed to be the biggest piece of glass ever produced by placing solid chunks of glass on a mould and "sagging" them into a single piece under intense heat; this process is said to reduce bubble inclusions and to be easier. Borosilicate glass was used by Corning Glass Works for its low expansion, thermal resistance and mechanical strength.

REDESIGN IN EPOXIDE

Two versions of a component for air break switchgear: right, an aluminium base plate to which are fitted S.R.B.P. tubes and copper conductors, and left, an epoxide moulding of the same unit that eliminates machining and fitting. The mouldings are made by J. R. Ferguson (Electrical Engineers) Ltd. for Federal Pacific Electric Co., U.S.A.

E.M.D. 1796 for further information



moorings for **BIG** *ships*

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Controlled Slip Differential

BRITISH RACING CARS have for many years made good use of a form of limited slip differential to prevent violent wheel spin when cornering under power or when accelerating from start or from slow speeds. It is an American company, however, who have first developed a controlled slip differential for passenger cars and lorries. The Eaton Manufacturing Co. have developed and are producing a unit for one of the large motor car companies in the U.S.A.; it is to be offered as optional equipment in 1960. Its object is to increase the driving torque when a vehicle is operating on slippery roads or in mud by minimising wheelspin which may occur under these conditions using a conventional differential. Licence negotiations are at present being conducted with a leading manufacturer in this country.

Stainless Steel for Shock Tubes

A HYPERSONIC SHOCK TUBE, the general principle of which is based on the sudden release of pressurised gas, is now under construction at the National Physical Laboratory, Teddington, and will be able to simulate some or all of the conditions applicable to the flight of missiles at extreme speeds in the upper atmosphere. To collect data on the behaviour of the gas flow during its few thousandths-of-a-second duration, when free-flight stagnation temperatures of the order of 8,500 deg. C. may be achieved, complex electronic equipment is required.

For the purpose of studying the physics of air at very high temperatures, stainless steel has been used for the shock tube, bars in lengths varying from 18 in. to 7 ft. 6 in. being specially bored with a 2-in. diameter hole to close tolerances.

The required aerodynamic performance of the shock tube calls for extremely high "driver" pressure in the chamber, or breech, of the shock tunnel. Typical operating conditions call for the containment of about 1 cu. ft. of hydrogen at a pressure 1,000 times greater than that of the atmosphere. This gas is then released, by rupturing a diaphragm, into the working section of the tube. The effect of the apparatus is to simulate flight at speeds up to about 18,000 m.p.h. at heights over 150,000 ft. (30 miles).

Aluminium on the Roads

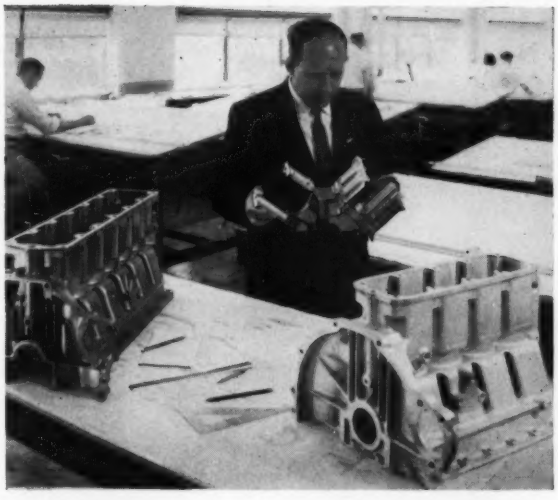
IT IS OBVIOUS, to those who seek rather more than streamlining and automated controls in their up-to-the-minute motoring, that aluminium is fast becoming a very significant material in motor car production. This is by no means restricted to engines. The Lancia Flaminia, for instance, already uses a wide range of alloys for parts of the steering gear, brake assemblies and body panels, as well as for the engine. In the U.S.A., General Motors Corp. have carried out considerable research into its use for cylinder blocks, while recent negotiations for diecasting machinery suggest that Russia is contemplating a diecast aluminium cylinder block, probably for a 1¾-litre diesel engine.

This year's Motor Show in London revealed this trend even more clearly. It is also apparent that some British manufacturers while not saying too much about it, have been doing intensive development work in this field. Two engines of particular interest have recently been announced: one is the Coventry Climax four-cylinder overhead-camshaft aluminium alloy engine, which uses renewable slip-fit liners and cast-iron valve seatings; the other is the Aston Martin DB4, which is a six-cylinder engine using wet liners.

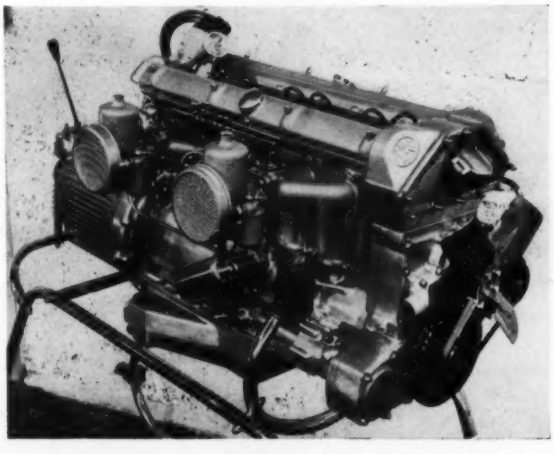
The great virtue of using aluminium is the weight reduction, which is highly desirable to offset the ever-increasing total weight of vehicles. Among its disadvantages are a high thermal expansion rate and a low modulus of elasticity; the latter is a particular problem in obtaining (without increased mass) the rigidity necessary to prevent premature bearing failure.

One important way to improve overall weight reduction is to concentrate initially on the engine. An aluminium engine can weigh up to 200 lb. less than a comparable cast-iron one, but, because the lighter engine needs less structure to support it, it can result in lighter tyres and brakes and better weight distribution.

A development which makes aluminium engines more practical is that of high wear-resistant alloys which eliminate the need for cylinder liners. To achieve this, the final adoption of a material is determined by the successful solution of metallurgical, production and cost problems. The first of these involves selection of materials which have satisfactory wear, corrosion and mechanical properties.



Two aluminium cylinder blocks designed and die cast by Doehler-Jarvis division of the National Lead Co.



Aston Martin DB 4 engine which uses a cast aluminium cylinder block with wet liners of chrome-vanadium iron.

Another method of combating cylinder wear is to use suitable coatings such as chromium, iron and electroless nickel plate, oxide type coatings, sprayed steel, molybdenum and aluminium or its alloys. According to General Motors, some cylinder bores sprayed with molybdenum showed good performance, whereas chromium-plated bores occasionally showed excessive wear at the top of the ring travel. The wear-resistant aluminium alloys, including the high silicon materials, showed satisfactory wear characteristics when tested on the dynamometer and under field test.

Since progress in the solution of some of the metallurgical problems has been significant, foundry techniques are also of interest. Some designs have been produced with diecasting in mind, as, for example, the aluminium block made by the Doehler-Jarvis division of the National Lead Co. in the U.S.A. This project is an important step, for its design (which is applicable to all V-8 engines blocks) eliminates undercuts, projections and blind passages, and allows for the efficient mass production by diecasting. In addition, smooth uniform lubricating and cooling passages are cast directly into the block permitting unobstructed flow and eliminating costly machining operations. Double-wall construction is used to increase the strength and rigidity.

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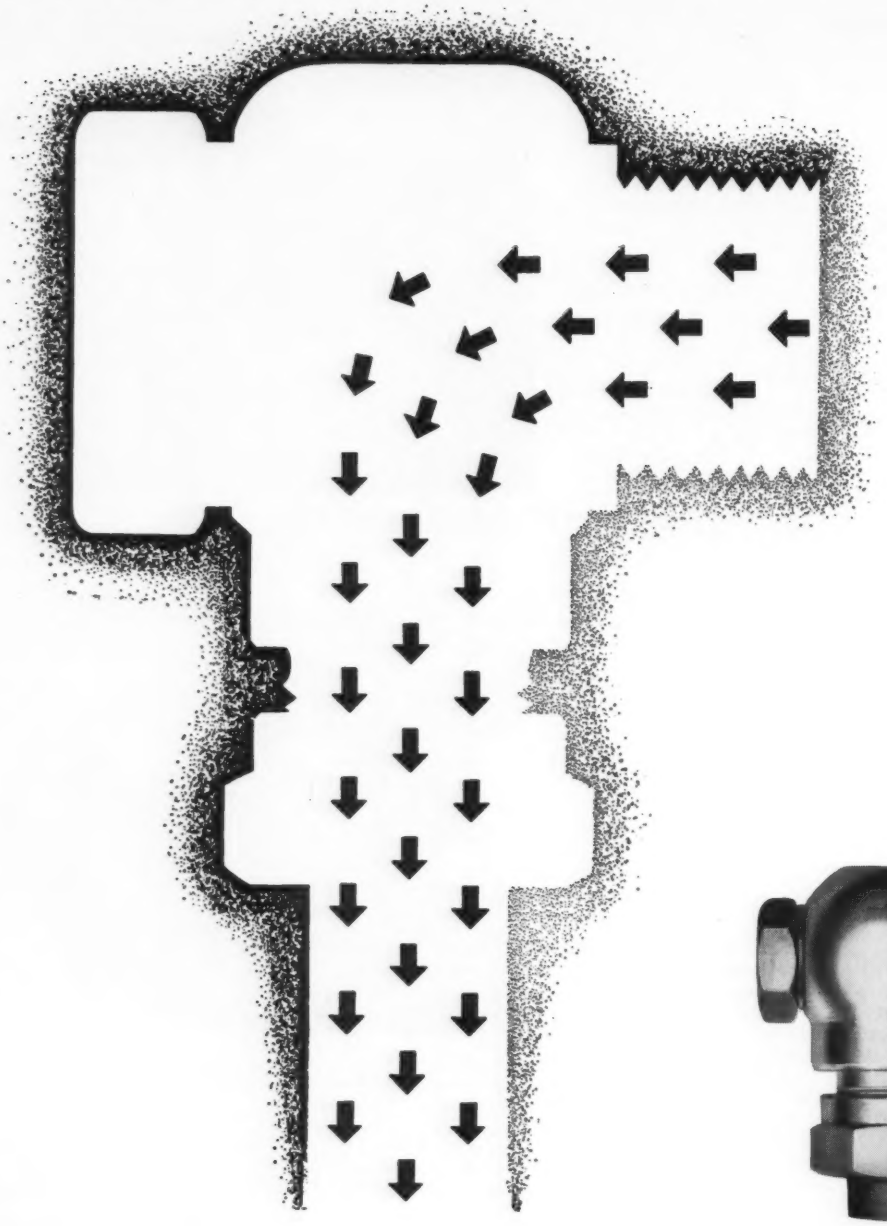

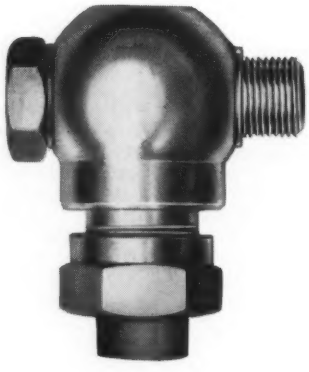

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Engineering Design Conference

WITH MORE THAN THREE MONTHS still to go, a large number of registrations has already been received for the Engineering Materials and Design Conference that is to be held at Earls Court in London early next year. A registration form, together with details of speakers and the papers they will deliver at the conference, is included as a loose inset in this issue, but further copies of the form may be obtained by writing direct to The Secretary, E.M. & D. Conference, Drury House, Russell Street, London, W.C.2, so that early application may be made. Tickets for the conference are transferable between members of any one concern.

The conference and exhibition will take place from February 22-26 and will be the first of their kind ever to be held in Britain. Subjects scheduled for discussion during the various sessions of the conference will be dealt with broadly under the headings of materials, components and design factors.

High-temperature Plastics

EFFORTS TO INCREASE the heat resistance of reinforced plastics materials have been directed mainly towards making the contact resins more heat resistant, and to developing fabrication and low pressure curing techniques for the phenolic and silicone resins which were known to possess inherent heat resistance. These programmes resulted in the triallyl cyamurate polyesters and heat-resistant epoxy, phenolic and silicone resins, each of which has found important uses. Recent programmes have resulted in silicone-modified phenolics with additional improvements in heat resistance. The net result to date is that high strength reinforced plastics are available for continuous use at 300 deg. C. and at 400 deg. C. for shorter periods.

Commenting on this at the recent U.S. Ordnance Materials Research Conference, Mr. R. C. Tomashot said that although it has taken great efforts to reach this point, development has been quick because of the vast background of industry in organic polymers. There is little possibility of obtaining a further significant increase in heat resistance of resins based on wholly organic polymers but the relatively new field of inorganic polymers has great potential of providing resinous materials that are thermally stable up to 540 deg. C. For use above this temperature, work has already been initiated on completely inorganic, non-polymeric reinforced laminates.

Successful development of resin or matrix materials for use above 400 deg. C. will present the additional problems of reinforcement integrity at these temperatures. At the present time the glass fibre reinforcement being used is basically the same material as used in 1942. However, comparative studies have shown that at 400 deg. C. the glass reinforcement is beginning to lose strength. To provide higher heat-resistant reinforcements, programmes have been underway for several years to develop high temperature-resistant fibres based on refractory oxide-type materials.

One aspect of reinforcement development which has significantly progressed is the development of high modulus glass fibre. Investigation of reinforced plastics as a primary aircraft structural material have repeatedly shown that the mechanical property most deficient is a low modulus of elasticity. Changes in the glass fibre composition have produced a high modulus fibre which in turn offers a 40 per cent increase in this property of the laminate.

IN NEXT MONTH'S ISSUE . . .

Principal features planned for the January issue of

ENGINEERING MATERIALS AND DESIGN include:

Photo Linear Projection
A new illustration technique for the senior draughtsman.

Selection of Gaskets
How to choose the right materials for specific environments.

New Uses for Beryllium
First of two articles on its application and handling.

How Design Can Affect Metal Finishing
Design-stage factors that may influence metal finishing costs and processes.

Grey Rigidex polythene and white Styron polystyrene used for the top and lid of the Gordon-Miller spin dryer—a notable new application of plastics in kitchen equipmeut.

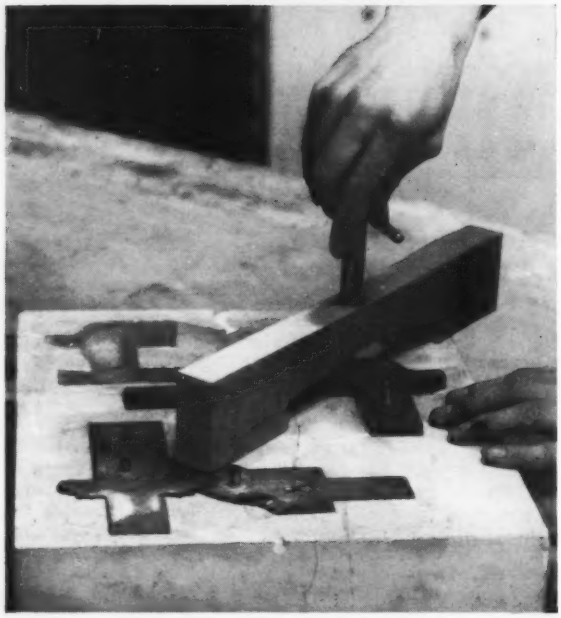
A.C. or D.C.

ONE OF THE LATE ARRIVALS at the Motor Show in London provided not only speculative thought for future trends of automobile electrical equipment, but also illustrated anglicised U.S. engineering at its best. The Chrysler Valiant, for example, was the only production car incorporating as standard equipment, an a.c. alternator with six in-built silicon-diode rectifiers, which were developed from a new guided missile system.

The modern luxury car carries a host of electrical devices in the form of cigar lighters, hood-folding and window-operating mechanisms, heating and lighting points. The conventional size of d.c. generator and battery is unable to provide the capacity for all these accessories, as has been shown on police cars demanding large current consumption for transmitter/receiver radio equipment. According to the Chrysler Corp., the main reason for using a.c. equipment in the Valiant was the saving in cost, space and weight, rather than current consumption, but the increasing electrical complexities of modern automobiles may show the wisdom of accepting the a.c. system.

In this country, a.c. equipment has been developed and fitted to fire service vehicles, police cars, long distance coaches and to certain town buses, the latter offering the possibilities of improved internal lighting using fluorescent tubes. It has considerable advantages where the engine speed is highly variable with long periods at tick-over or where the current demand is high. A further advantage is that the a.c. alternator is less complex than its d.c. counterpart and will function under the most arduous conditions with less attention.

The reluctance of car manufacturers in this country to accept the a.c. system may be due to tooling costs, although the electrical equipment manufacturers have already in existence suitable units which could go into mass production. The modern semiconductor will undoubtedly play a considerable part in reducing both size and weight of a.c. equipment which may ultimately lead the car manufacturers to accept this system.



Pattern making with epoxy resins. Above: pouring the plaster mould. Below: withdrawing master patterns using a bridge and screw.

Epoxies for Patternmaking

ALTHOUGH EPOXY RESINS were first used in patternmaking several years ago, their acceptance has been generally slow. Some companies regard them as too expensive, or object to their use on the ground that they give rise to dermatitis. A detailed account of their use at Hadfields Ltd. was given recently in Sheffield by their pattern shop manager, Mr. R. G. Gardner, to the National Trades Technical Societies.

The master, which is made preferably in two halves, must be made with the necessary contraction allowance for the material of the finished casting. It is then given a smooth varnish coating and a fine grained plaster is poured over it. A mixture of equal parts tallow and oil is used on both master and box to prevent sticking. When firm, the mould is withdrawn, a wooden bridge and screw being used to avoid breaking the plaster, and dried in an infra-red oven. When cool, the mould faces are given two coats of fluid wax which is polished with a soft cloth or brush to give a glossy finish.

For large patterns, some form of lightening out, either by using a plaster or Vermiculite core is used. Filler to make bulk can be of marble flour, powdered aluminium, slate powder and even sawdust. The mixture of resin, hardener and filler is then put on a vibrating surface to allow air bubbles to escape.

When the resin has set it is then placed in the oven for about twelve hours. Surface surplus resin on the mould face is machined level on a pattern miller. The mould is finally broken away to leave the pattern.

For larger hollow patterns a thixotropic mix of resin and laminating glass fibre is made. This mix enables the resin to stick to a vertical wall without falling down. The mix is applied with a stiff brush to the mould face, strips of glass fibre matting or roving (already impregnated with resin) being then laid on the mould. The walls are built up to around $\frac{1}{4}$-$\frac{3}{16}$ in. thick. In this way quite large patterns can be made.

Careful observation of simple precautions, such as wearing rubber gloves when mixing the resin and washing hands in warm soapy water, eliminates any need for worry about infection. It is claimed that considerable savings could be effected with epoxy patterns for, although the resin is expensive, labour costs are low, particularly when a multiple mould, containing a number of identical patterns must be produced. In some instances it is possible to make the baseboard as well out of epoxy resin, these being suitably reinforced. In addition the patterns could be easily repaired if damaged, although they were generally more robust than patterns in wood. The finish and accuracy attainable are said to be superior to wood.

Technical Trends at the Motor Show

ALTHOUGH ANALOGUE COMPUTER STUDIES have been used in the U.S.A. to improve suspension systems, and were employed in the design of the Citroen DS 19, British manufacturers generally have been conservative in their approach to new methods of studying design problems. While there are difficulties in adequately defining the complex non-linear behaviour of the component parts of advanced design suspension systems, co-operation between the electronic and motor industries could give impetus to motoring safety and comfort; E.M.I. Electronics, Ltd., demonstrated at the Motor Show in London the advances made in analogue computer techniques in the hope of encouraging a free exchange of ideas.

In the range of car accessories seen, there are two new electrical r.p.m. indicators designed to dispense with a mechanical drive from the engine. The Smiths revolution indicator is a precision instrument designed to form the basis of a development for an electrical speedometer. The complete unit consists of two component parts, indicator head and a transmitter which in effect is a small alternating current generator, driven mechanically from the engine. As the engine speed varies, the output voltage varies proportionally and is supplied to the indicator head which contains a moving coil mechanism, the current having been previously rectified.

The electronic revolution indicator manufactured by the Key Leather Co., Ltd., works on a completely different principle: the spark impulses from the engine ignition circuit are transformed and rectified to a d.c. output which is exactly proportional to the speed of the engine. The accuracy of the moving coil indicator is substantially independent of the state of the battery sparking plugs or contact breaker.

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TRAINING FOR VERSATILITY

AN imaginative training scheme for apprentices being operated by Birlec Ltd. is likely to ensure a flow of skilled engineers with versatile minds for the company in the future.

Its most notable aspect is its flexibility, for it faces the fact that most boys in their mid-teens are unlikely to know what branch of work they will eventually want to follow. Therefore, the scheme provides a general engineering training in the first twelve months, and gradually specializes more and more in the following four years.

During the first year, the apprentices alternate from week to week between workshop and drawing office instruction. This is supplemented by lectures introducing the types of materials handled and the manufacturing processes in common use.

With this, there are studies in economics and foreign languages, visits to other firms, and talks by managers of various departments to show how the various technical activities of the company are inter-related.

At the end of the first year, the apprentice is thus able to produce simple engineering drawings, and has had some practical training in the various trades. By this time, too, he has given a general idea of his special aptitudes and he is accordingly grouped on either a craft or technical class. All apprentices spend their second year in a separate production workshop, using actual production work as examples, but training is still largely common to the two groups, so that a transfer may be made from one to the other without much difficulty.

The craft apprentices concentrate on their first and second choice of trade and are expected, at the end of their second year, to choose the craft in which they will complete their training. Technical apprentices spend a third year in at least two production departments, working alongside skilled operatives. They then spend their last two years in the engineering or other technical departments.

An interesting feature of the scheme is the encouragement of particularly able technical apprentices to broaden the field of their knowledge by concurrently studying two related subjects, such as mechanical and electrical engineering, or metallurgy and chemical engineering. After the first year, outstanding boys are granted two days a week to study the required subjects.

Birlec believe that the junior management of production departments should be drawn equally from craft and technically trained apprentices, and those in the craft group who are regarded as promising are encouraged to take advanced training courses in appropriate subjects.

By a scheme devised in this way, Birlec hope to provide each apprentice with the best training possible for his career and to make him a potentially valuable member of the organisation in the future.

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BETTER REWARDS FOR ENGINEERS

WHEN any section of the community is told that it is being underpaid there is rarely any strong disagreement by those concerned, and therefore we feel sure that most of our readers will not quarrel with the statement recently issued by the Engineers' Guild that the earnings of professional engineers in this country are inadequate. This comment was based on the results of a survey of information supplied by over 6,000 engineers, only half of whom earned more than £1,200 in 1956. Only one in four received over £1,600, whereas in the U.S.A. it is said that only one in ten engineers earns less than £1,650 within one year of graduation.

Such comparisons should not be taken too seriously, because the figures, if they are to mean anything, must be corrected to allow for the difference in the cost of living and other factors which are not strictly comparable between the two countries. More important, however, is the standard of living which engineers can maintain relative to other professions in their own country. The survey rightly points out that the living standards of engineers in this country have dropped in proportion to that of many other occupations and this is causing engineers to emigrate to areas of the world where they can command better rewards, or else they leave the profession for other occupations, such as sales, with its lure of the expenses account and greater personal freedom.

Salary is by no means the only factor causing unrest among the more active members of the engineering profession, for as Mr. J. H. Jellett, chairman of the Engineers' Guild, points out when commenting on the survey: "There must be greater incentives for the qualified engineer and possibly a further lightening of taxation. . . ." This touches on a point that is just as important as salary.

Many engineers could obtain promotion by changing to another company, but usually they are only offered £50-£100 increase per annum by way of inducement. Bearing in mind that a change of job may mean uprooting the family, changing of schools and friends, and, most important of all, forfeiting all benefits of superannuation, which may have been built up over many years, it is not surprising that engineers with a sense of responsibility are not easily tempted to take the risks that new employment may bring.

In spite of the fact that the Guild represents only about 5 per cent of the engineers in this country, it has already obtained some notable benefits for its members; but whatever the outcome of these efforts employers should heed the warning that all is not well. Some firms have complained that they are having difficulties in obtaining engineering staff. While the emphasis on technical progress continues—there is every reason to believe it will increase—there will be a shortage of engineers, but intelligent young men of the type we need will not be encouraged into engineering by the thought that unless they are very lucky or outstandingly brilliant they are unlikely ever to earn more than a salary in the region of £1,500 a year.

The Editor

PHOTOELASTICITY CAN HELP THE DESIGNER

For many problems, photoelasticity is the only practical method of stress analysis. This article illustrates its possibilities by a series of studies of specific problems that can face the designer

by J. R. DIXON, B.Sc., A.F.R.Ae.S. *

PHOTOELASTICITY can play an important role in design; not only can it assist in the verification of assumptions used in theoretical stress analysis, but it can be used to obtain elastic stress distributions in problems not amenable to mathematical calculation. There are also many problems, mainly three-dimensional, for which photoelasticity is the only means at present of obtaining a solution. The need for more accurate stress analysis in engineering design is increasing, especially when designing for fatigue as well as static strength and perhaps a minimum weight requirement.

During the past fifty years photoelasticity has grown into a well-established method of experimental stress analysis, and many large engineering firms as well as universities and research organisations now possess active photoelastic laboratories.

In the photoelastic method of experimental stress analysis, a scale model of the prototype is examined by polarised light; the model is made of a transparent plastics having special optical and mechanical properties. If the model is loaded under a system simulating that applied to the prototype, then under polarised light the model exhibits patterns of interference fringes, from which, by methods derived from the theory of elasticity, the magnitudes and directions of stresses at all points of the model can be calculated.

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The stress distributions obtained by the normal photoelastic method outlined above are strictly only applicable to the prototype within the linear stress-strain range of the prototype material; the principles of similarity are used to deduce the prototype stresses. If the photoelastic results give very high elastic stresses in the regions of stress concentration, suggesting that yielding would occur in the prototype, then the redistribution of stress due to yielding can, in general, only be estimated.

Three-dimensional photoelastic stress analysis at present is mainly carried out by means of the "stress-freezing" method. The loaded plastics model is subjected to a heating cycle which has the effect of "freezing" the model in its stressed state. Thin slices can then be cut from the model (without any relief of stress), and the stresses at internal points investigated; in this way a complete picture of the three-dimensional stress distribution can be built up.

The way in which photoelasticity can help the designer is illustrated on these pages by a survey of some photoelastic work specifically carried out as an aid to design. Rather than give full details of each investigation, an attempt has been made to show the photoelastic approach to a design problem, and what sort of results a designer can expect to get from a photoelastic investigation.

Two-dimensional Problems

DRILLING OF CRACKS—Fatigue and manufacturing cracks are sometimes stopped by drilling small holes at the ends

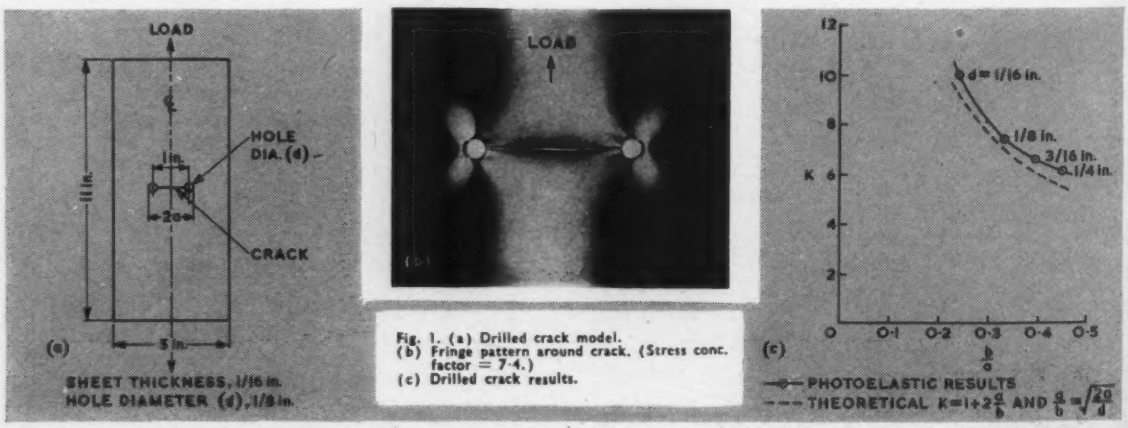


Fig. 1. (a) Drilled crack model. (b) Fringe pattern around crack. (Stress conc. factor = 7·4.) (c) Drilled crack results.

of the crack; this has the effect of reducing the stress concentrations at the ends of the crack. The variation of the stress concentration factor (K) at the end of the drilled crack with hole diameter was studied by two-dimensional photoelastic tests on an Araldite model.

Details of the model are given in Fig. 1 (a). Fig. 1 (b) is a photograph of a typical isochromatic (line of constant maximum shear stress) fringe-pattern showing the high stresses at the ends of the drilled crack.

The results of the investigation are plotted in Fig. 1 (c). The broken curve is the theoretical solution for a central ellipse in a plate of infinite width under tension; the ellipse having its major axis equal to the drilled crack length and its radius of curvature at the ends of its major axis equal to the radius of the drilled holes. There is a good agreement between the theoretical and experimental results; in fact, the difference will be mainly due to the use of a plate of finite width in the photoelastic tests.

It is interesting to note the difference in K for cracks drilled by $\frac{1}{16}$-in. and $\frac{1}{8}$-in. diameter holes: :

$K = 10{\cdot}1$ $\frac{1}{16}$-in. diameter holes
$K = 7{\cdot}4$ $\frac{1}{8}$-in. diameter holes

where $K = \dfrac{\text{Maximum stress at ends of drilled crack}}{\text{Nominal stress across uncracked section of plate}}$

These kinds of results show the necessity for careful attention in the design of repair schemes.

SQUARE CUT-OUT WITH ROUNDED CORNERS—Cut-outs in stressed sheets, and in the walls of pressurised vessels such as aircraft cabins, always present a problem, and the design of edge reinforcing is by no means straightforward; it is possible with a badly designed reinforcing to introduce a stress concentration higher than that in the unreinforced sheet.

The stress distribution in the region of a reinforced cut-out is strictly three-dimensional; however, useful data can be obtained rapidly with a two-dimensional analysis. The photoelastic results are then in the form of mean stresses through the thickness of the sheet and reinforcing.

Fig. 2 (a) gives details and main dimensions of a photoelastic model with cut-out and reinforcings. The reinforcings were glued to the sheet with cold-setting Araldite 103; carried out with care, models can be fabricated this way without causing initial gluing stresses.

Tests were carried out as follows:

Stage (i) Plain sheet with cut-out.
Stage (ii) As in (i) with reinforcing (1) on one side of the sheet.
Stage (iii) As in (ii) with reinforcing (2) on the other side of the sheet.

Fig. 2 (b) is a photograph of the isochromatic fringe-pattern in stage (ii), showing the point of maximum stress in the corner radius near its run-out into the straight edge. Fig. 2 (c) compares the stress distribution around the inside edge of the cut-out for all three stages. There is a considerable reduction in maximum stress with reinforcing (1), but no apparent significant reduction with the addition of reinforcing (2).

The stress concentration factor (Fig. 2 (c)) for stage (iii) from photoelastic measurements was $K = 2{\cdot}0$. Extensometer measurements on metal specimens geometrically similar to the photoelastic model in stage (iii) gave $K = 3{\cdot}0$ on the edge of reinforcing (1) and $K = 1{\cdot}0$ on the edge of reinforcing (2). The mean of the two extensometer readings is 2·0, which indicates agreement with the photoelastic observations; more important perhaps, it shows the danger of using two-dimensional photoelastic analysis on three-dimensional problems.

GEARBOX INPUT PINION—Although a photoelastic analysis of gears will give immediately the maximum elastic stresses in the fillets of the models, it is difficult to apply these results directly to the prototype when such factors as the effect of skin hardening and residual stresses must be taken into account; but the photoelastic method is ideal for measuring the relative effects of various gear geometries on the stress distribution and can help sometimes in the diagnosis of trouble.

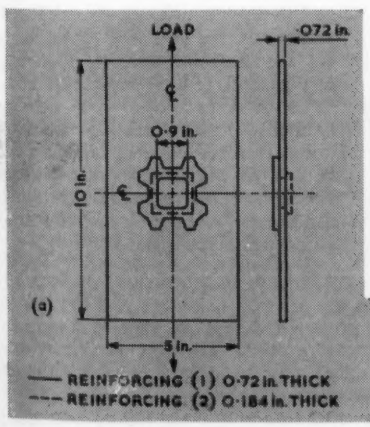
Two designs of pinion were tested, the spur teeth in each design differing in fillet geometry and pressure angle. The object of the photoelastic tests had been initially to compare the stress distribution in the two designs; but it was discovered that the variation in fit of the pinion on the splined shaft, influencing the transference of load between the two members, had such an effect on the stress distribution that a comparison of the two designs was not directly possible.

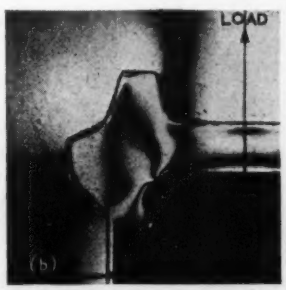
Although the variation in fit of the pinion (which was made of Araldite for these tests) on the metal splined shaft would be worse than that of the corresponding prototype parts, the photoelastic results did show qualitatively that the pick-up of load of the pinion from the splined shaft could be a possible source of trouble by increasing the maximum tensile stress in the fillets of certain teeth.

The front cover of this issue shows typical fringe patterns indicating the high stresses in tooth fillets.

STRESS DISTRIBUTION IN DOG TEETH—It was required to check the validity of preliminary predictions made relative to bending stresses, shear stresses and stress concentration factors occurring at the roots of a particular design of dog teeth. The investigation was carried out with two-dimensional photoelastic models of various cross-sections of the dog teeth.

Several tooth profiles were tested; a typical model and





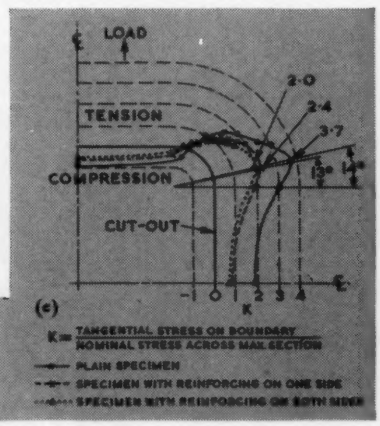
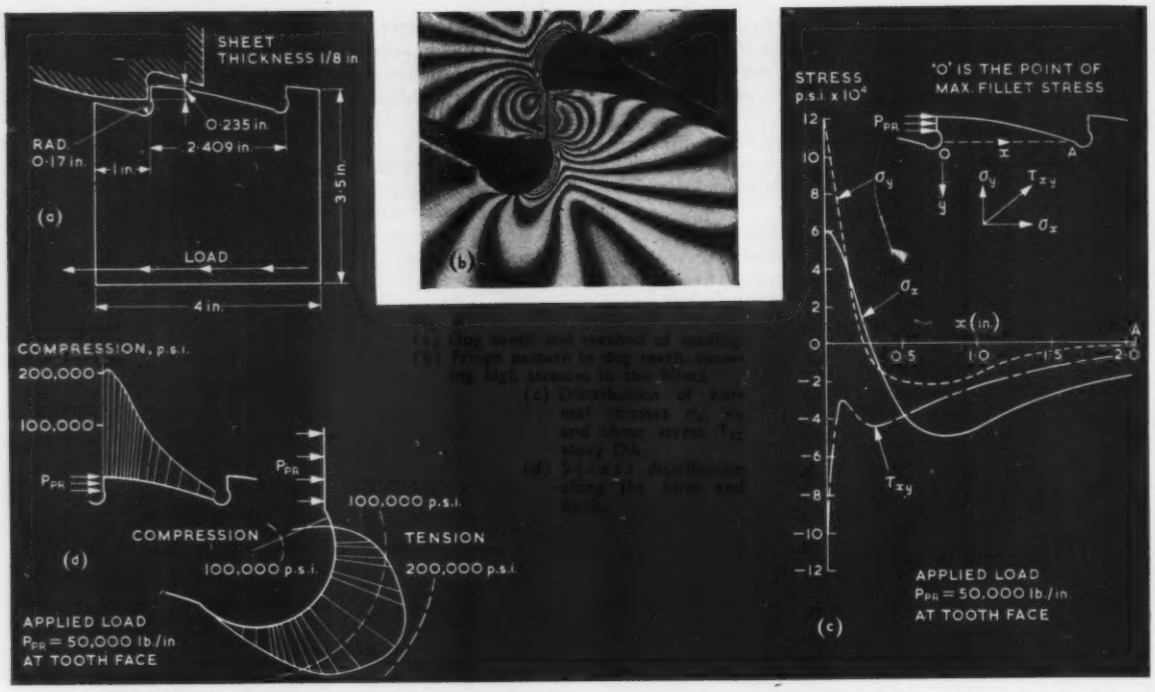


Fig. 2. (a) Square cut-out and reinforcings.
(b) Fringe pattern in cut-out reinforced on one side. (Stress conc. factor = 2·4.)
(c) Variation of tangential stress along boundary of cut-out.



the type of loading are shown in Fig. 3 (a). The distribution of the normal stresses σ_x, σ_y and the shear stress τ_{xy} across the root of the tooth is given in Fig. 3 (c) for a prototype load (P_{PR}) of 50,000 lb./in. tooth face. σ_x, σ_y and τ_{xy} were obtained from a numerical integration of the elastic equations of equilibrium using photoelastic data. The elastic stress distribution along the fillet and flank of the tooth (Fig. 3 (a)), also for a prototype load of 50,000 lb./in. tooth face, is given in Fig. 3 (d).

Further tests showed that the maximum stress in the fillet was virtually the same whether one or two pairs of teeth were in contact (with representative loads).

The photoelastic tests showed that the maximum elastic stresses occurring in the fillets were of considerably greater magnitude than those predicted by preliminary design calculations. As a possibility of reducing these high fillet stresses, an attempt was made to determine an optimum fillet profile in the nature of a "streamline" fillet. Several streamline fillets were investigated, but no significant reduction in maximum stresses was obtained compared with the circular fillet as in Fig. 3 (a), and it was concluded that taking into account the permissible geometry and type of loading of the dog teeth, the circular fillet was near enough the optimum fillet contour.

Three-dimensional Problems

Pin Bending—A thick Araldite plate with a push-fit central Araldite pin, the pin stiffened by an axial brass wire, was loaded as in Fig. 4 (a). Due to the bending of the pin under load the problem was three-dimensional and the frozen-stress photoelastic technique used. The mean maximum shear stresses on the hole boundary through the whole plate thickness were obtained; thin slices were then cut from each face of the plate, and the maximum shear stresses determined on the hole boundary in the edge slices. This gave a comparison between the mean stresses through the plate and the stresses on the outer faces, and hence a measure of the effect of the transverse bending of the pin under load.

Photoelastic models differing in plate thickness were analysed. The variation of τ_e/τ_m with D/t is plotted in Fig. 4 (b)

where τ_e = maximum shear stress on hole boundary on outer face of plate;

τ_m = maximum shear stress on hole boundary as a mean through the whole plate thickness;

D = hole diameter; and

t = plate thickness.

The photoelastic results for $D/t<1$ showed the stress distribution to be less severe than that assumed in a standard lug design method.

Stress Distribution in Shear Pins—A series of tests was carried out to investigate the stress distribution in standard shear pins as currently used on service aircraft. The pins were plain or with axially drilled holes, or with circumferential grooves at the shear planes. Although holes and grooves may be used effectively to give the pin the required static strength, they may produce stress concentrations which could prove sources for fatigue cracks.

The investigation was made by means of the three-dimensional frozen-stress technique. The nature of the analysis required slicing the pins in planes at right angles to each other; this necessitated the use of two similarly frozen pins. The test rig was therefore made to load two pins at the same time. Pins and test rig were manufactured in Araldite B.

The pin with axially drilled holes proved particularly interesting because of the high stress concentration on the boundary of the inside hole in the shear plane. Fatigue cracks could only be produced (in the region of high stress concentration) when abnormally severe test loading conditions were employed for prototype parts.

Gearbox Layshaft Stress Distribution—It was required to determine the stress distribution and regions of peak stresses in a proposed design of joint at a pinion-layshaft neck. The nature of the assembly was such that the photoelastic method was the only known method of obtaining the required stress distribution.

The prototype layshaft assembly consisted of a layshaft

bolted to an internal gear, with the pinion forced into the V-groove of the layshaft by a clamping nut. The investigation covered two prototype loading conditions: one a nut preload of 28 tons, the other a nut preload of 28 tons with a lateral bending load of 14·7 tons.

The assembly and loading are shown diagrammatically in Fig. 5 (a). The nut preload was simulated by a couple (M) applied to layshaft and pinion, and the side load (W) applied to the pinion at four discrete points through a loading tree and reacted at bearing positions (P and Q). The photoelastic models were made full-scale and all components in Araldite B.

The stress analysis was carried out using the frozen-stress technique. A separate model was needed to cover each loading condition; each model was "frozen" in its stressed state and the layshaft subsequently cut into thin slices. An optical analysis determined the three-dimensional state of stress in each slice, and a complete picture built up of the stress distribution around the pinion-layshaft neck. The magnitudes and directions of principal stresses were determined from the slices using oblique incidence methods (a technique where polarised light is passed through the slice at an angle to the normal to the plane of the slice).

Nut Preload Only. Although under load the pinion-layshaft bearing surface is continuous on the inside edge of the V-groove, it is discontinuous on the outside edge of the groove due to tooth gaps. Prior to slicing, a qualitative examination with polarised light (Fig. 5 (b)) showed some circumferential stress variation around the layshaft just outside the V-groove, due to the tooth gaps. It was thought that the tooth gaps might possibly cause a variation of peak stresses in the V-groove radius, and the layshaft was purposely sliced so that any such variation would be detected.

There were two regions of peak stresses:

1. In the radius of the V-groove (points N-M, Fig. 5 (c)).
2. In the radius where the inside edge of the V-groove runs into the shaft (point L, Fig. 5 (c)).

Unfortunately (2) was undercut when being machined and was therefore not representative of the prototype.

Fig. 5 (b) shows the method of slicing, and Fig. 5 (c) the variation of tangential stress σ along the V-fillet boundary. Within experimental error there was no variation due to the pinion tooth gaps of the maximum V-fillet stresses around the V-groove.

Relative to a prototype nut preload of 28 tons, the peak principal stresses σ_P and σ_Q (Fig. 5 (b)) in the V-groove radius were:

$\sigma_P = 26{,}000$ p.s.i. radial tension,

$\sigma_Q = 13{,}100$ p.s.i. circumferential tension.

Nut Preload with Lateral Bending. The model was supported against bending loads at bearing positions on the pinion and internal gear. Light alloy half-hoop supports were used at the bearing positions, and the hoop diameters were machined slightly oversize to allow for the differential thermal expansion of metal half-hoops and Araldite model at the stress-freezing temperature, so that at this temperature (120 deg. C), the half-hoops would be neat fits at the bearing positions.

The nut preload was applied as before as a couple to the layshaft and pinion by means of a simple lever mechanism. The side load was applied at four discrete points along the length of the pinion through a loading tree; this ensured an approximate uniform loading along the length of the pinion, independent of small deflections.

As in the model with nut preload only, there were two regions of peak stresses:

1. In the radius of the V-groove.
2. In the radius where the inside edge of the V-groove runs into the shaft.

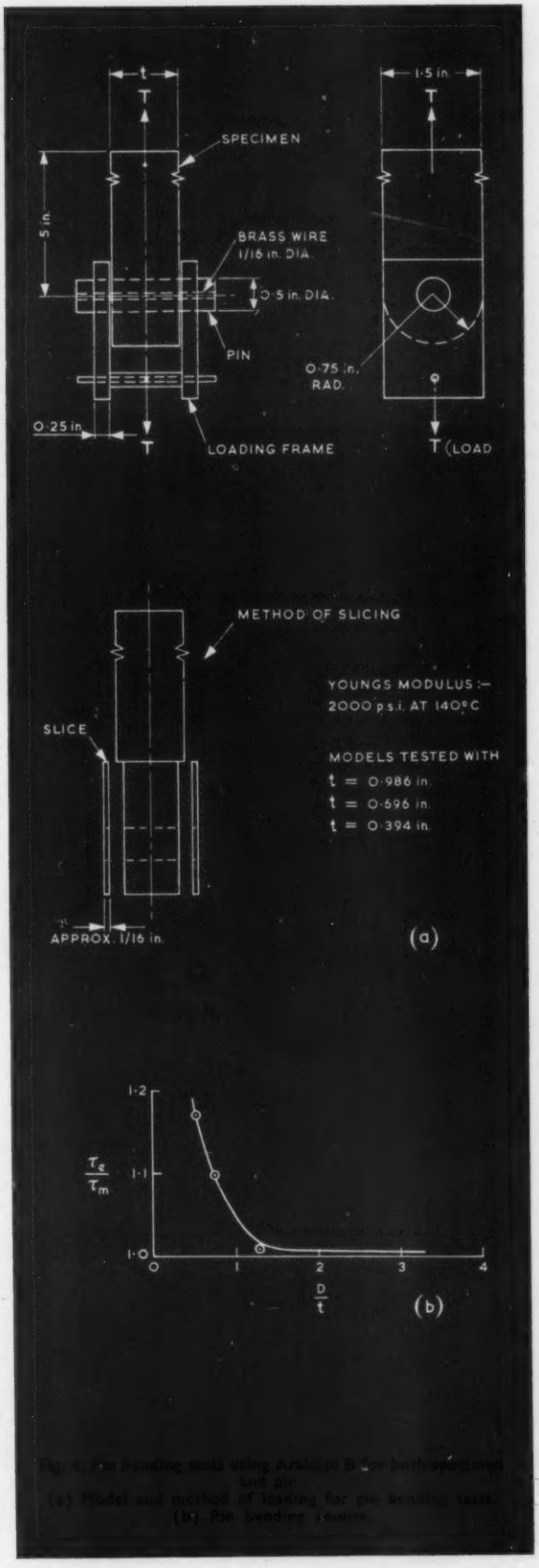


Fig. 5. Pin bending tests using Araldite B for both specimen and pin.
(a) Model and method of loading for pin bending tests.
(b) Pin bending results.

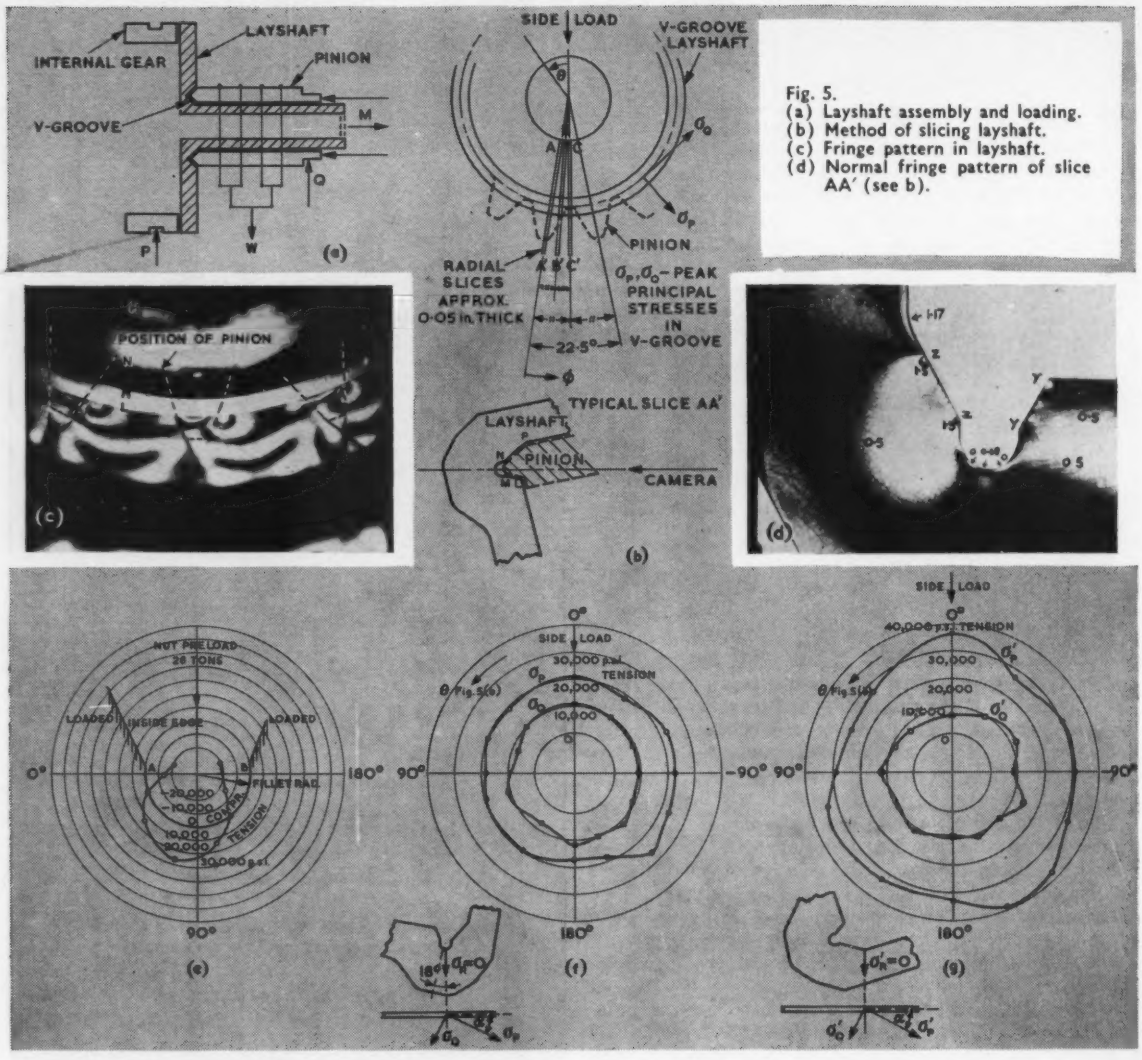


Fig. 5.
(a) Layshaft assembly and loading.
(b) Method of slicing layshaft.
(c) Fringe pattern in layshaft.
(d) Normal fringe pattern of slice AA' (see b).

The variation of peak principal stresses σ_P and σ_Q in the radius (1) are presented as polar plots in Fig. 5 (f). Any small variation in fit of pinion in the V-groove and misalignment of the model in the loading rig is reflected in asymmetry of the curves about 0° axis (side loading plane of action). The maximum and minimum values of σ_P are 26,300 p.s.i. and 16,800 p.s.i. tension, giving a cyclic variation of 9,500 p.s.i. per revolution of layshaft. The directions of σ_P and σ_Q were approximately radial and tangential relative to the circular V-groove, i.e., α (Fig. 5 (f)) was approximately zero.

The variation of peak principal stress σ_P^1 and σ_Q^1 in the radius where the inside of the V runs into the shaft are presented as polar plots in Fig. 5 (g). The maximum and minimum values of σ_P^1 are 39,400 p.s.i. and 26,000 p.s.i. tension, giving a cyclic variation of 13,400 p.s.i. per revolution of layshaft. The directions of σ_P^1 and σ_Q^1 were approximately normal and tangential to the circle round the shaft at fillet (2), i.e., α^1 (Fig. 5 (g)) was approximately zero.

A photograph of a typical frozen isochromatic fringe pattern is shown in Fig. 5 (d), where by the three-dimensional stress distribution in the region of the V-groove can be obtained. The point of maximum tensile stress on the V-groove fillet at 0·68 fringes and points of zero stress on the V-groove fillet boundary (at 0 fringes) mark the transition from tension to compression. The point of maximum tensile stress on the fillet above the V-groove is at 1·17 fringes.

It is interesting to note that the maximum stress occurs in the radius above the V-groove, and not in the V-groove fillet, as was originally thought.

Conclusions

It has been shown in the above descriptions of some typical photoelastic investigations how useful information can be obtained by applying photoelasticity to design problems. A photoelastic analysis can often be carried out relatively quicker and cheaper than other forms of experimental stress analysis. If in some instances the information gained can suggest a reduction in the amount of full-scale prototype testing, then the time and expense of the photoelastic work will be well repaid.

As new ideas and techniques in the application of the photoelastic phenomena are developed, designers in the near future will be able to apply photoelasticity confidently to a wider class of problems.

Acknowledgments

The author wishes to thank Bristol Aircraft Ltd. for permission to publish the photoelastic results described in this article, which is based on work carried out in the company's engineering development laboratories.

Grateful acknowledgment is also made to the Photoelasticity Section, University College, London, for help with the front-cover illustration.

1959

INTERNATIONAL PLASTICS EXHIBITION

THE 1959 Plastics Exhibition at Düsseldorf displayed an unmistakable trend towards the greater use of plastics in technical applications, and suggests that engineers in continental Europe are acutely aware that the exacting demands of modern engineering and consumer products can only be met by using new and better materials. Such factors as good strength-to-weight ratio, good anti-friction properties and good sound insulation have enabled plastics to be used for a wide variety of machine parts. These materials, although usually more expensive than metals, which they sometimes replace, have in many cases enabled the overall production costs to be reduced by virtue of economical moulding techniques. They have also shown improved life in applications where they replace bronze or acid-resisting steels for the motor and chemical industries in such items as pump bodies and impellers.

Outstanding impressions of the exhibition from the engineering aspect are the large range of gears and bearings (plain and rolling element types) made partially or wholly from plastics, the widespread availability of plastics pipe and storage vessels for corrosion resistance and the growth of foam plastics which, in Germany at any rate, now exceed foam rubber in production.

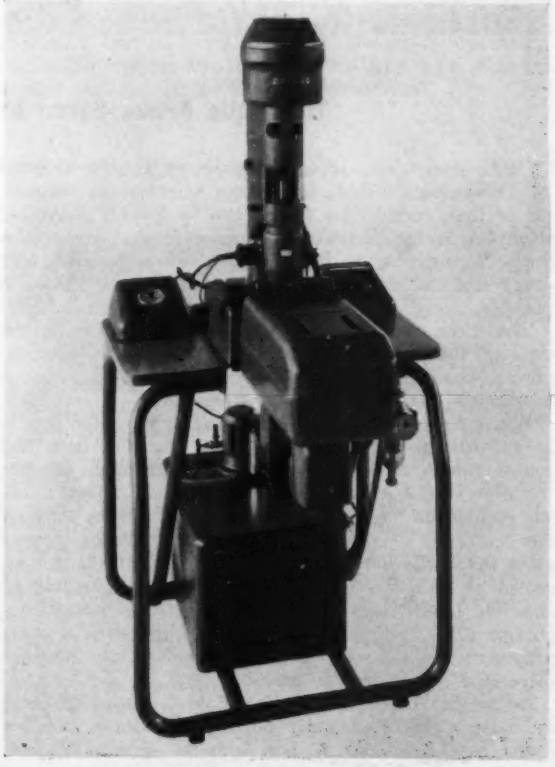
Foam products were of special interest for the variety of materials being manufactured and also for the versatility of their applications, either alone or as composites with a surface skin of conventional material such as aluminium. In flexible form, foams are finding increasing use as safety components in transport vehicles, and in rigid form for filling spaces between thin sheets for the production of items such as vehicle doors. Here the rigidity and low weight have obvious advantages for aircraft and passenger-carrying land vehicles.

At the last Plastics Fair in 1955, low-pressure polythenes to supplement the conventional high-pressure types were shown for the first time. These plastics have made noteworthy progress since that time, particularly for injection moulding and extrusions. In Western Germany this development appears to have pushed forward more rapidly than in other countries. No really new materials were in evidence, although development of nylon, polycarbonate and polypropylene plastics for engineering uses appear to be far more advanced than in this country. On the contrary, the use of polyester-glass fibre materials for car bodies and boat hulls does not appear to have developed so rapidly. P.V.C. has been widely used in Germany for many years in chemical plant and other applications where resistance to corrosion was necessary, but many other plastics have now joined this field. For ducting and piping, glass-reinforced polyester or epoxy resins are now being used as well as polythene and p.t.f.e., where corrosive conditions are exceptionally severe.

The ever-widening range of thermoplastic materials has led to new designs of processing machinery such as injection moulding machines and extruders having automatic control for manufacture of parts of different wall thicknesses and volumes; also a hydraulic pressure gauge and axial screw shifting device which enables extruding operations to be easily adapted to the plastics material being processed. In order to assist the economic production of complicated mouldings, greater use is being made of hydraulic injection moulding machines incorporating a plasticising screw. This permits an increase in plasticising capacity, more rapid moulding cycles and more homogeneous mixing of pigments and polymer. The wide range of vacuum-forming machinery and large numbers of firms now manufacturing this type of plant are indications of the importance of this relatively recent development in manipulation of plastics. The fact that large components can be manufactured economically and in sizes outside the range of injection moulding machines, as well as the general similarity to deep drawing of metal, should arouse the engineer's interest in this method of shaping plastics.

The exhibition, claimed with some justification to be the largest plastics fair in the world, included exhibits from sixteen countries. The engineering interest in the processing plant and machinery was considerable, but of greater importance were the very fine mouldings and fabrications now manufactured on a production basis for engineering components both small and large. British engineers should consider the significance of this.

Some materials and components of interest to engineers which were seen at the exhibition are listed on page 642.



Arburg vertical bench-type injection moulding machine constructed on the building block system, with hand, pneumatic or fully-automatic cycling control.

NEW IDEAS IN DESIGN

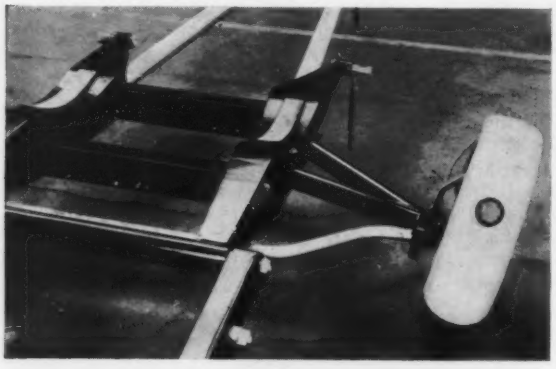
Outstanding products in current manufacture

Combined Torsion and Towing Bar in Trailer Suspension

FOR the transport of a small compacting roller of the type seen on road works and building sites, Blackburn (Dumbarton) Ltd. have developed a trailer of elegant simplicity. The springing system is unique in that extensions of the two torsion bars serve also as a towing bar.

The trailer chassis is of all-welded construction. Through the vertical webs of the chassis side members are welded tubular pieces in which the torsion bars are carried. Welded tubular wish-bones are through-bolted to the torsion bars and carry stub axles welded in position. At the rear of the chassis is an anti-roll bar which is stated to provide 2 deg. roll stiffness at 30 m.p.h. A folding ramp is fitted to facilitate easy loading, and the compacting roller nests in concave depressions in the side members to which strips of shock-absorbent material are fitted. When loaded, the mass of the compacting roller is vertically over the wheels and little effort is therefore required to raise the tow bar.

This design would appear to have interesting possibilities for other types of trailer, for there is the absolute minimum of redundant structure. By altering the position of the tie-plate at the end of the tow bar, it would be possible to vary the torsion bar stiffness to suit different sizes of loads.



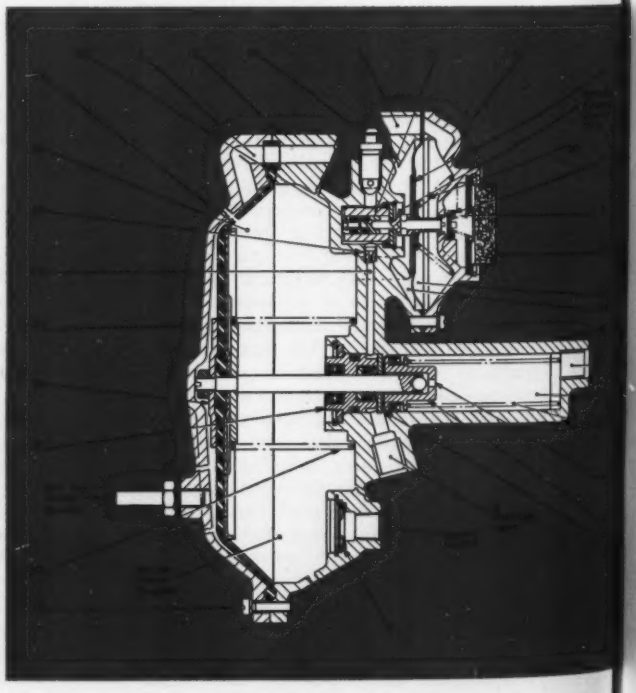
Hydraulic Brake Servo uses Intake Manifold Vacuum

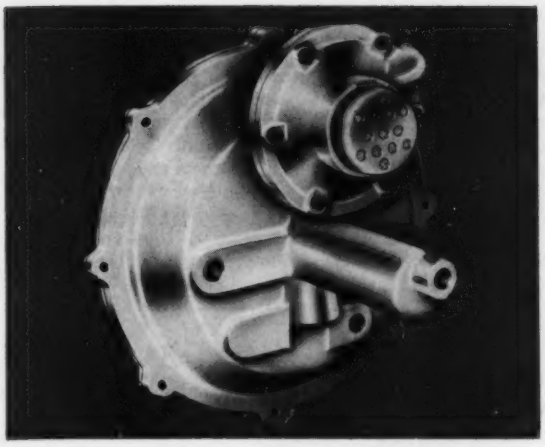
THE Mot-A-Vac, recently introduced by the Clayton Dewandre Co. Ltd., is a device whereby the ordinary car or light commercial vehicle can be quickly converted so that its hydraulic braking system is assisted by vacuum power from the engine. It is claimed that installation is very simple and that smoother and more progressive braking is possible.

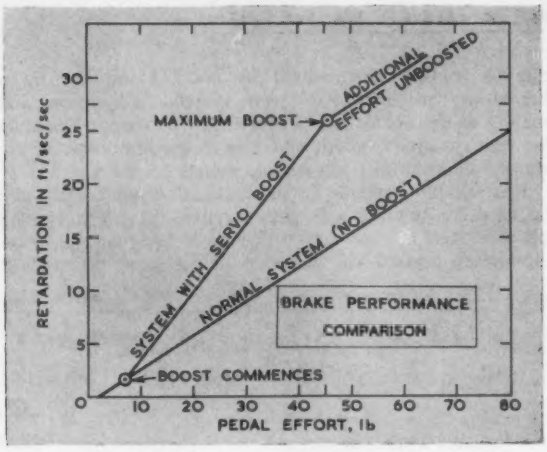
The three major assemblies, which together form the unit, are shown in cross-section. These consist of a vacuum power chamber, a hydraulic slave cylinder and a hydraulically-actuated control valve.

When the brake pedal is not being applied, the unit is in a "vacuum suspended" condition. Vacuum from the engine intake manifold is transmitted through vacuum check valve (17) to power chamber (26). Vacuum enters valve chamber (10) via passage (24) and passes through the centre of diaphragm assembly (5), past the poppet valve (6) to the valve chamber (9). Chamber (9) is connected to chamber (27) by tube (1), thus transmitting manifold (constant) vacuum to both sides of power diaphragm (22). The relative positions of the various components in the sectional view correspond to this "vacuum suspended" or "released" position.

As the brake pedal is applied, fluid is caused to enter the slave cylinder through port (14) in slave cylinder piston (15) and through port (12) to wheel cylinders. Simultaneously, pressure is built up at the left of the control valve piston (3), moving the diaphragm stem (5) which seats on the poppet valve (6) and shuts off flow of vacuum







between valve chambers (9) and (10). Further movement lifts the poppet valve (6) and admits atmosphere through the air cleaner to valve chamber (9) and power chamber (27).

Vacuum differential moves power diaphragm (22), bringing the ball end of the push rod into contact with port (14) in the slave cylinder piston (15), thus trapping fluid in the slave cylinder. Hydraulic fluid then under pressure is transmitted to the wheel cylinders through port (12), thus applying the brakes.

The vacuum differential across the control valve diaphragm (5) is balanced by master cylinder hydraulic pressure at the left side of valve piston (3). In this way the hydraulic output pressure in the slave cylinder is in proportion to the master cylinder input pressure. The fluid displacement at the right of slave cylinder piston (15) is the same as the displacement at the left of slave cylinder piston (15) and valve piston (3). The driver thus has pedal position as well as pressure control, giving him complete feel of the brakes. Total output pressure is equal to that from power diaphragm (22), plus pressure from the master cylinder on the left of the slave cylinder piston (15).

After the required degree of brake application has been obtained, the control valve position of the unit reaches a holding position in which the poppet valve (6) is seated in the valve cover and on the diaphragm stem. Hydraulic pressure at the left of piston (3) is balanced by the vacuum differential across diaphragm (5) and any variation in hydraulic input pressure will produce a corresponding result in vacuum differential and hydraulic output pressure.

When the Mot-A-Vac is fully applied, the valve piston (3) has moved completely to the right against its stop and the poppet valve (6) is lifted from its seat. Power chamber (9) is then completely exposed to atmosphere and maximum possible differential exists across power diaphragm (22). Any further increase in hydraulic output pressure comes from the master cylinder only.

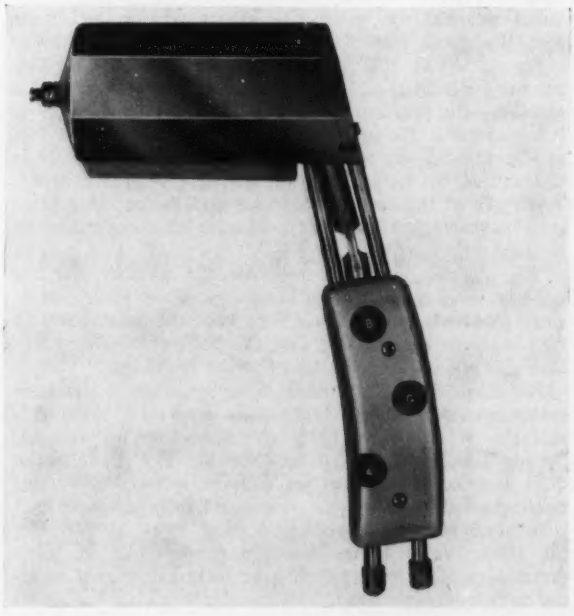
The safety feature claimed for the Mot-A-Vac is that the brakes can be applied in the conventional manner in the case of possible vacuum power failure. In this case, fluid under master cylinder pressure by-passes directly through port (14) to the wheel cylinder lines.

2,000 deg. C. Brazing Torch uses Air and Gas Preheater

BY close attention to the physical principles involved, the Hot Blast Torch, now being marketed by Sunvic Controls Ltd., produces a sharply defined heat zone having a temperature capable of fusing recrystallised alumina (2,050 deg. C.).

The conventional Bunsen burner has a temperature of approximately 1,850 deg. C. at the hottest part of the flame. Although higher temperatures are possible with the compressed-air blow torch, much heat is dissipated by vortices in the poorly defined heating area and both gas and air are wasted.

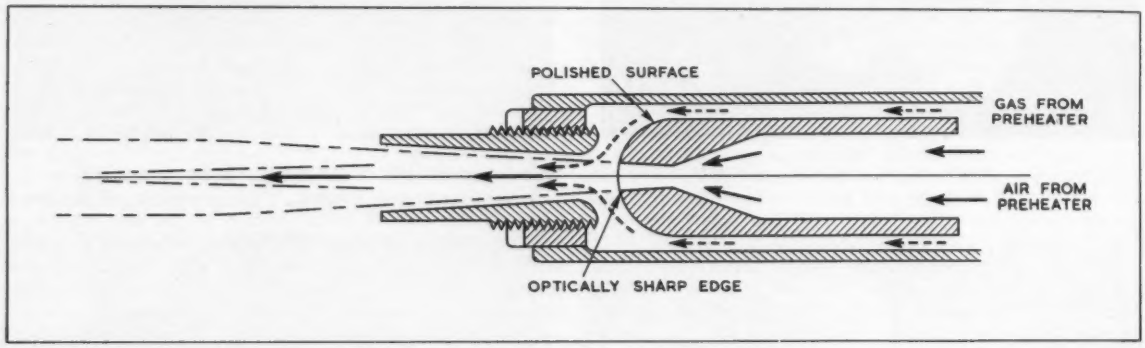
The accompanying diagram shows the essential features of the nozzle of the Hot Blast Torch. Before entering the nozzle, both the mains gas, which is at ordinary supply pressure, and the air (at 0·5 p.s.i.) are pre-heated to around 750 deg. C. by a separate burner in the body of the torch. The mixture ignites spontaneously and it is claimed that the flame cannot be blown out and will burn even when played into an inert atmosphere. The dimensions of the nozzle, the rate of flow and the rate of diffusion were chosen to obtain the optimum efficiency in burning, while the polished gas passages and sharp exit to the venturi ensures that the flow is non-turbulent. This characteristic not only makes possible the concentration of heat in a well-defined zone, but also enables more heat to be concentrated on the component to be treated as the heat loss,



due to cold-air entrainment by vortices initiated by a breakaway in flow, has been avoided. Oxidation and scaling of the nozzle has been avoided by care in selecting the best materials, which give rise to the minimum of unwanted deposits due to catalytic action on the gas.

Remarkably versatile in its applications, the torch can be used for brazing with pure copper, or eureka-brazing of thin steel sheets and autogenous welding of brass, aluminium and Al-Mg alloys. With the latter materials it would seem that far less attention to cleaning is necessary. Although not hot enough to weld steel sheet autogenously, it will weld a pair of soft iron wires twisted together. The torch has also been used for silver soldering stainless steel with a noticeable reduction in hardness due to carburisation. In addition, almost perfect holes of 0·07 in. diameter can be produced in thin steel sheets.

The torch was developed from a laboratory model designed and made by Dr. Burch of Bristol University.



Copy Milling Head Features Coaxial Design

THE Path-O-Mill (made by Pathex (Canada) Ltd.), a copy milling head which can be attached to any standard vertical milling machine, universal mill or any slow table planer, employs a compact design which keeps inertia of the moving parts in the transfer system to a minimum.

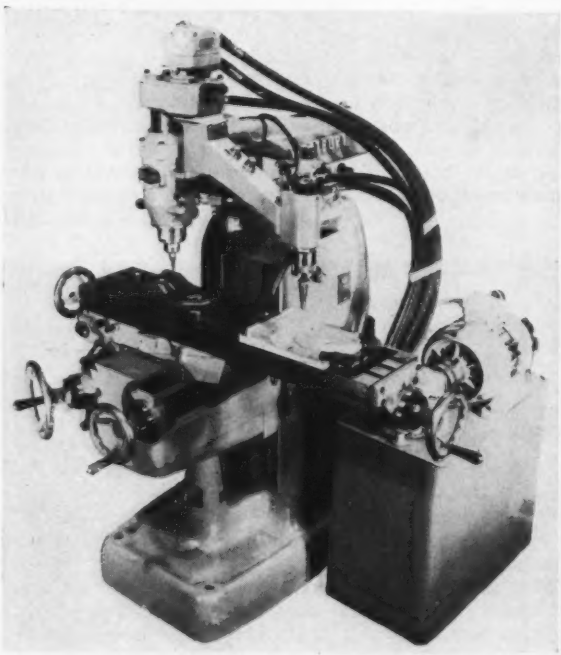
Fig. 1 shows a simplified diagram of the principles generally applied in conventional units. With the actuating cylinder mounted beside the quill, any action of the cylinder sets up a moment A-D-B-C. This force occurs in the form of angular motion in respect to the quill, causing deflection P-U and resultant error K. This motion must be opposed by the supporting forces of the quill housing (G-H or F-E) in order to produce linear motion of the quill. These forces cause considerable friction and consequent wear of the quill. The higher friction and wear naturally cause loss of sensitivity and accuracy.

Fig. 2 shows the principle of the Path-O-Mill. The actuating piston is an integral part of the quill (L). The actuating and reacting forces are co-axial, thus eliminating P-U deflection. No opposing forces (such as G-H and P-E in Fig. 1) wear out the barrel. All of the reacting force is transmitted to the cutter, thus giving greater sensitivity. The force of the vertical tool load and the reacting force are always in equilibrium, so there is no lag and a minimum of duplication error.

The integral design of the hydraulic cylinder and the quill housing is claimed to ensure perfect pressure lubricated movement of the quill. The constant pressurised oil film between the housing and the quill eliminates backlash and maintains a constant friction coefficient.

The head uses a standard Westbury 8-speed drive or optional oil-injection lubricated hydraulic infinitely-variable transmission for extra-fine fingertip control. Speeds from 40-3,000 r.p.m. are possible. The stroke of the quill is 4 in. and it runs on double Timken taper-roller bearings.

Accurate three-dimensional tracing work is possible. the tracer valve being micrometer adjustable in three dimensions. The head can also be locked and used as an ordinary quill-type head.



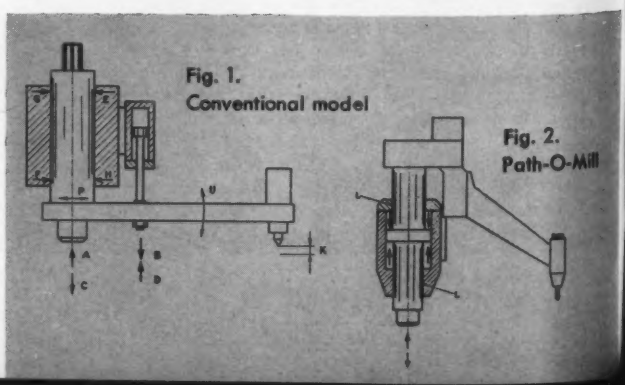


Fig. 1.
Conventional model

Fig. 2.
Path-O-Mill

HOW TO SELECT ELECTRICAL HEATING ELEMENTS

No heating process can offer the same degree of flexibility in use as electricity. To meet complex demands, manufacturers have produced a broad variety of elements, many of which are discussed here in relation to their correct application

by W. R. EADES*

MANUFACTURERS have been quick to realise the increasing popularity of electrical heating in the industrial world and have produced a wide and comprehensive range of heating elements and appliances in order to satisfy the inevitable demand. Many new and ingenious types have appeared, and it is safe to predict that, however startling or unconventional a problem may be presented, it will be quickly solved after due consultation by the intelligent application or adaptation of standard ranges.

Indeed, it would be difficult to envisage a heating problem which could not today be solved by electrical means. This is, of course, a most abrupt departure from the industrial heating conception of, say, twenty years ago; even in those comparatively recent days electrical heating was regarded with disfavour and suspicion, particularly where inflammable liquids were concerned. It is now generally accepted that in this field electrical methods can usually be made safe, and possess the advantages of cleanliness, ease of control, consistency of results and the complete absence of combustion fumes.

Materials Used

The commonest materials in general use are metallic alloys containing nickel and chromium, or nickel, chromium and iron. This type of material possesses good average characteristics and is suitable for operating temperatures up to about 1,100 deg. C. It is appropriate to mention here that "operating temperature" indicates the surface temperature of the element itself, and is the theoretical maximum temperature attainable in the appliance. The actual temperature available depends upon a number of other factors.

These alloys, based on nickel and chromium, are manufactured in the form of wire or ribbon, which is frequently formed into an open spiral to ensure optimum heat concentration.

At temperatures of up to about 800 deg. C. nickel-chromium alloys are practically everlasting, but if used at higher temperatures they are subject to corrosion and eventual destruction due to atmospheric and other contamination. A further manifestation, which is aggravated by high-temperature working, is an ageing process which produces a gradual increase in electrical resistance with a corresponding reduction in heat output. This must be counteracted either by increasing the supply voltage or by providing additional elements which can be switched in to maintain the overall output.

By the use of carefully-selected ingredients and by close manufacturing control, manufacturers have succeeded in producing refined versions of the basic nickel-chromium alloy having considerably enhanced properties. For example, Hall & Pickles' Nicralloy has a continuous service rating of 1,150 deg. C., does not become brittle after prolonged use (as the basic alloy does tend to do), and is corrosion-resistant to the extent that its service life is almost indefinite at temperatures up to 1,000 deg. C.

TABLE 1. General applications of heater element types

Application	Type of Element or System
Air-drying, curing, thermo-setting:	
non-inflammable	Open radiant (refractory or woven)
	Dielectric
	Infra-red
inflammable	Flameproof radiant panel
	Finned tubular
	Dielectric
	Infra-red
Water heating	Copper-sheathed immersion
Oils and fats	Immersion (steel sheathed)
Corrosive liquids	Immersion (stainless steel or Monel sheathed)
Heat treatment: metals	Tubular
	Armoured flexible
	Induction
non-metals	Radiant panel
	Infra-red
	Dielectric
Air and gases: in ducts	Open wire wound
	Tubular
	Woven
in pipes	Flexible tape
	Armoured flexible
	Induction
Process vessels, melting pots	Flexible heating jacket
	Shaped heating jacket
	Induction (with or without surface heater at base)
Heat-treatment ovens and furnaces	High-temperature alloy spiral
	Silicon carbide tube
	Molybdenum disilicide tube
	Flexible ceramic-mat (for portable furnaces)
Melting furnaces	Resistance heating
	Electric arc
	Induction
Brazing and soldering large surfaces	Flexible ceramic-mat
Surface hardening	
Small-scale brazing and soldering	High-frequency induction

* C. J. Foote & Partners Ltd.

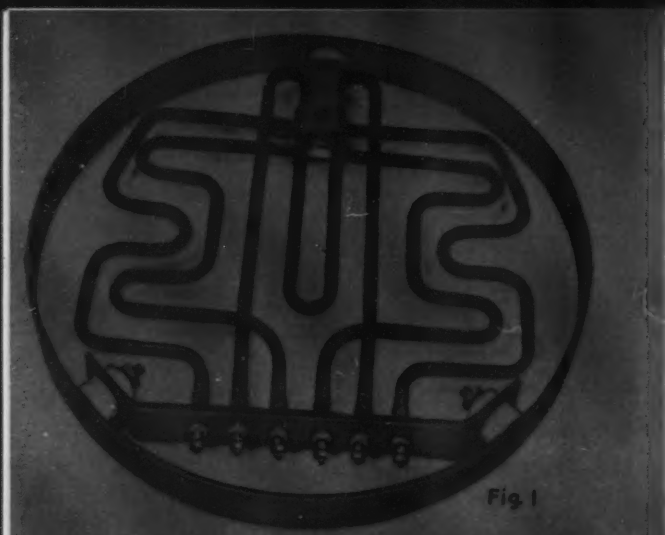


Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 1. A Backer variable-wattage tubular element for an air heater.

Fig. 2. Finned tubular elements by Tetra Engineering Co.

Fig. 3. A Geo. Bray finned strip heater element.

Fig. 4. Flexible knuckle refractory heater by Hedin Ltd.

Fig. 5. Vitreosil immersion heater with p.v.c. cap (Thermal Syndicate Ltd.).

Kanthal, another proprietary metallic alloy, is marketed in various grades, each of which is stated to be superior to standard nickel-chromium alloys in many respects; exceptional resistance to attack by sulphur and its compounds and an ability to withstand unusually high surface loading (i.e., watts per unit area of the conductor surface) are among the properties claimed for this material. For all the grades the maximum working temperature is higher than for any nickel-chrome alloy, but in spite of this the average life under similar conditions is far longer.

For temperatures higher than those attainable with metallic alloys it has been customary in the past to use the rarer metals such as platinum, tungsten, molybdenum or tantalum. These, however, suffer from inherent disadvantages, notably the extremely high cost of platinum, and the necessity for a protective atmosphere in furnaces using the others, since at elevated temperatures they rapidly combine with air and with many of the gases to be found in a furnace atmosphere. This applies also to carbon which, though possessing an extremely high melting point, must be very carefully protected by an inert gas if its working life is to be of any significant length.

Where the presence of a protective atmosphere is not required for other reasons (for example, to achieve a minimum of scaling), elements based on silicon carbide are finding increasing favour in the field of high-temperature furnace construction. One example of this is Crusilite, marketed by the Morgan Crucible Co. This material is suitable for temperatures up to about 1,500 deg. C., is very tolerant towards frequent switching (which curtails the life of most metallic elements), and possesses favourable ageing characteristics. The rate of ageing is both low and uniform, which means that elements can be connected in series without the risk of uneven heat distribution occurring as the elements age.

Another non-metallic element developed for high-temperature work in recent years is Kanthal-Super. Based on molybdenum disilicide, this material has a surface working temperature of 1,600 deg. C., and can be operated at very high surface loadings. From the economic standpoint its principal advantage is a complete freedom from ageing in service; old and new elements can be interchanged in the same appliance without the necessity for adjustments to the supply, and the elements can be connected in series or in parallel to suit individual installation requirements.

At room temperature this material is brittle and must be handled carefully; on the other hand, above 1,100 deg. C. new material becomes ductile and at still higher temperatures it can be bent or wound into elements of desired shape. This does not, however, apply to elements previously used.

Types of Element Available

Such is the versatility of the electrical heating element that it can be moulded and adapted for use in practically any imaginable way. It occurs in such a variety of forms that the following survey of available types is necessarily on a very broad scale; space does not permit a detailed description of every variant.

RIGID TUBE—The open wire-wound type of rigid tubular element, familiar as the basis of the small domestic heater, consists of a winding of metallic wire (usually nickel-chrome) on a former of refractory material; fireclay and silica are the most usual. For industrial purposes (for example, the construction of furnaces), the wire-wound element is gradually giving way to the non-metallic refractory type, i.e., the refractory tube is itself the element. The salient properties of such elements (Crusilite, Kanthal-Super, etc.) have already been discussed.

Another form of tubular element is that in which an alloy heating spiral is embedded in a refractory material (usually

compacted magnesium oxide) enclosed in a tubular sheath. Originally developed for use in domestic cooker hotplates, this type of element lends itself readily to many industrial applications and is available in various sheathings to suit particular requirements. It is interesting to record that these elements are frequently called into service when an urgent heating problem presents itself. One such problem was the preheating to a uniform 200 deg. C. of an 11-ton, 14ft. × 10 ft. × 4 in. thick gas-duct at the Berkeley Nuclear Generating Station; using ordinary domestic cooker elements and thermostats, the job was completed on time without a single welding failure.

At the manufacturing stage these elements can be manipulated into turns of quite small radius, a property which confers considerable versatility. Fig. 1 is an example of this. For use as radiators or air-heaters the elements can be supplied fitted with closely-spaced fins (Fig. 2).

STRIP ELEMENTS—Although this type of element (usually wire-wound) can be obtained in open form for use in specified appliances, in its more useful industrial construction it is metal-sheathed and is eminently suited to such applications as the space heating of electric traction vehicles. Because of its flat shape it is very convenient for use where space is limited. However, a finned version possessing superior radiation characteristics is also available.

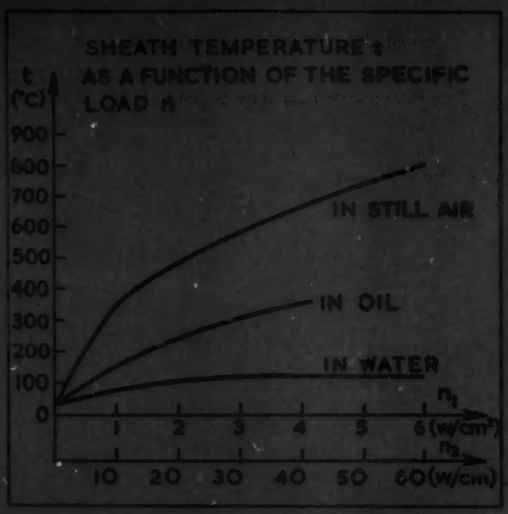
Frequently the strip is formed into a band which can be clamped to a curved object or vessel. For medium temperatures the strip or band is wound on mica, asbestos or glass fibre. "Knuckle" refractory heaters for heavy duties and high temperatures are made up of a series of interlocking refractories and are fully flexible (Fig. 4). Where temperatures do not exceed about 100 deg. C., it has been found practicable to embed a flat zig-zag of the wire in a thermosetting plastics which automatically spaces the turns and so provides an inexpensive element.

Of similar conception is the element embedded in the toughened glass of inspection windows. The object here is to heat the glass itself and thereby prevent misting or frosting; as only a low heat density is required, the wires can be very thin and widely spaced, and therefore do not affect the optical properties of the glass to any serious extent.[1]

FLEXIBLE ELEMENTS—By using interlocking beads of the refractory or insulating material, it has been found possible to construct tubular or strip elements which lose nothing in efficiency yet are flexible enough to be manipulated by the user. They can be bent to turns of quite small radius and are accordingly popular in the laboratory or during experimental and prototype work. As a protection against contamination by gases or the dripping of liquids, the element can be supplied enclosed and sealed in a flexible metallic sheathing; the life is prolonged thereby, and the sheathing affords some protection against mechanical damage. Where greater protection is needed, armoured flexible elements are available. These frequently employ the woven asbestos or glass fibre method of construction, which is fully flexible and capable of withstanding rough treatment in service.

WOVEN ELEMENTS—As the name implies, a weaving technique is used in the construction of these elements. Nickel-chrome or similar wire is woven into a network with filaments of an insulating material, usually asbestos or glass fibre. This type of construction originated in the field of load resistances, but it was soon realised that it offered an excellent medium for radiant panels and air-duct heating. Being to some extent flexible, it is easier to handle during installation and more robust in service than other types of open element. If desired, it can be made rigid by a process of impregnation with a suitable varnish; this has the effect of improving the overall insulation and is therefore an advantage where flexibility is not essential.

Development continues apace, and it has recently been



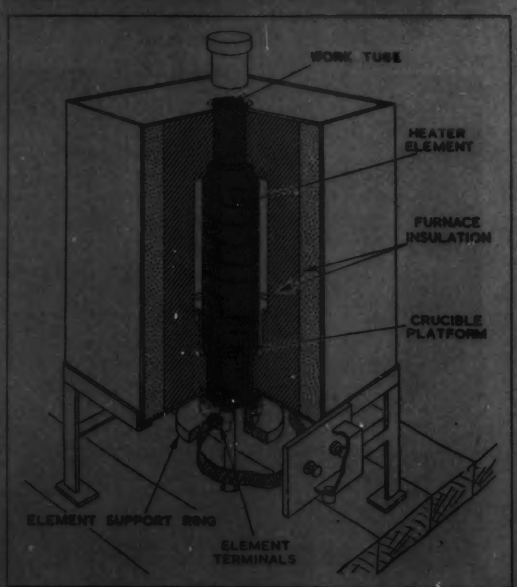


Fig. 6. Sheath temperature and surface loading in a Stabilag Makro tubular heater. (n_1 refers to length of 31 mm. dia. Makro sheath.)

Fig. 7. Pilot plant heated by looped mains frequency induction coils.

Fig. 8. Typical application of a Morgan Crusilite silicon-carbide tubular element.

TABLE 2. Typical resistance values of heater elements

	Eureka	Monel	Nickel	Molybdenum	Brightray S
Specific resistance, microhm/cm. (at room temperature)	49	48	9·0	5·21	110
Resistance, ohm/yd. (d = dia. in mm.)	$\frac{0{\cdot}00574}{d^2}$	$\frac{0{\cdot}00562}{d^2}$	$\frac{0{\cdot}001052}{d^2}$	$\frac{0{\cdot}00061}{d^2}$	$\frac{0{\cdot}01285}{d^2}$
Maximum working temp. °C.	300	500	600	2,000	1,150
Temp. coefficient of resistance	(0–200°C.) ± 0·00004	(20–100°C.) + 0·00045 (100–500°C.) + 0·0019	(20–100°C.) + 0·005	(20–100°C.) + 0·0047	(20–500°C.) + 0·000061

$$\text{Resistance} = \frac{\text{Specific resistance} \times \text{length}}{\text{Area}}$$

Resistance correction for temperature

$$Rt_2 = Rt_1 [1 + \alpha (t_2 - t_1)]$$

Where Rt_1 = resistance at temperature t_1;
Rt_2 = resistance at temperature t_2; and
α = Temperature coefficient of resistance.

reported that, in the U.S.A., woven elements have been successfully used in the difficult operation of brazing stainless-steel honeycomb. Owing to the flexibility of the element permitting intimate contact with the work, heat transfer by conduction was achieved and a comparatively low heat density required as a consequence.

This inherent property of the woven element has permitted the development of a wide range of heating jackets especially shaped to fit the contours of vessels or other objects. Maximum heat transfer is achieved by this method, with consequent economy in operation. Jackets of this type can be manufactured to practically any shape or size, and although their obvious application is in connection with the heating of liquids in drums and other vessels, they possess such attractive high-temperature and high-density qualities that increasing use is being made of them for such purposes as stress-relieving during large-scale welding operations.

Similar in its application, but quite different in its construction, is the ceramic-bead mat-type flexible surface heater. In this, interlocking ceramic beads carry hairpin-shaped resistance wires linked together during manufacture to form electrical circuits. This type of construction permits extremely small bending radii (down to 1 in.) along the axis of the beads. At right angles to this the minimum radius is 24 in. As with the woven heater, this heater can be applied directly to the work, with consequent efficiency and economy. This is not the limit of its usefulness, however; for example, by using bricks for support and thermal insulation, a portable furnace of any desired size and rating can be rapidly constructed. An example is shown in Fig. 11.

By suitable linking-up of the "hairpins", different wattage densities can be obtained at will over different portions of the element, to suit any particular requirement. For example, during the welding of a thin piece of metal to a thicker one, a uniform stress-relieving temperature rise throughout the workpiece can be easily achieved.

FLEXIBLE TAPES—An ingenious development is represented by the very comprehensive range of flexible heating tapes now on the market. Individual methods of construction of the element proper vary but slightly, most being in the form of a double length of resistance wire, suitably insulated and joined at one end of the tape. The connections are brought out at the other end of the tape, which is therefore a self-contained heater. But to cater for a wide variety of temperature and environmental requirements there is an equally wide choice of available outer coverings, ranging from quartz for temperatures up to 1,000 deg. C. to p.v.c. for temperatures not exceeding 80 deg. C. As may be

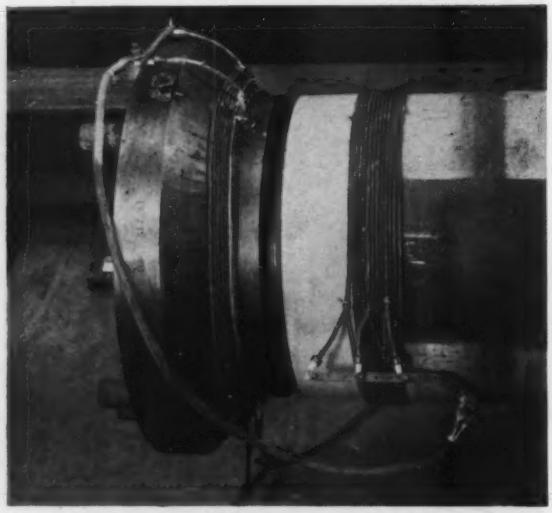


Fig. 9. Electrothermal Engineering armoured flexible heaters on a 20-in. pipe being prepared for welding.

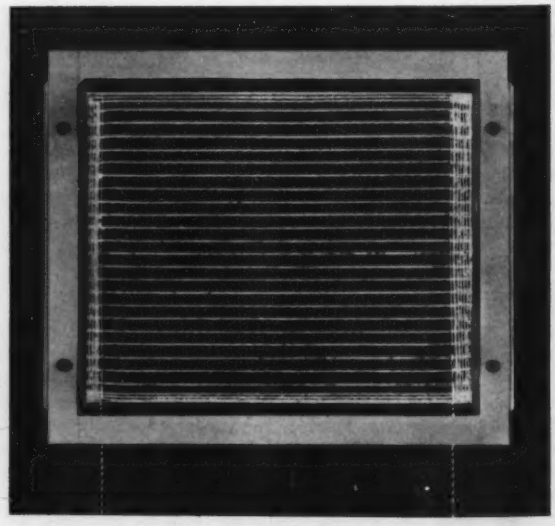


Fig. 10. Cressall woven asbestos heating net mounted in an insulated iron frame.

gathered, these tapes are intended for wrapping round the object to be heated, and are used extensively for the heating of pipe runs. On a vertical or inclined run it is customary to spiral-wind the tape on the pipe, but on a horizontal run straight tracing often suffices.

Flameproof metal-sheathed tapes are also available, but these are necessarily somewhat less flexible than the unprotected tapes.

IMMERSION HEATERS—An element intended for direct immersion in liquids must be constructed with particular regard for safety—from electric shock when water or aqueous solutions are involved, and from fire when the liquid is inflammable. This consideration apart, there is no basic difference in the construction as compared with, say, a typical tubular heater, but the external sheathing of the immersed portion must, of course, be selected to suit the particular liquid for which the heater is to be used. For water heating the sheath is generally of tinned copper, while stainless steel, Monel, Inconel or brass are used where oils, fats, or inflammable or corrosive fluids are involved.

For automatic control of the heating, the thermostat can conveniently be combined with the heater in the same housing, thus providing a neat self-contained unit. A further refinement is the withdrawable element, which can be withdrawn from its sheath (complete with thermostat, if fitted), leaving the sheath intact. This, of course, obviates draining-off and the breaking and re-making of seals when it is desired to change an element. (In this connection it is appropriate to mention that an immersion heater need not be a fixture in the appliance—tank, vat, or as may be. Portable heaters are available which are shaped for insertion in the open top of a vessel, the connector box, of course, remaining above the surface. This type of heater offers an advantage over the installed type for occasional use.

Other things being equal, it is an advantage to present the largest possible heating surface to the liquid, and to this end grouped heaters are available, some having as many as many as thirty-six units mounted on a flanged mounting boss. The units are usually arranged so that any heating core can be removed independently without disturbing the others or their connections.

CARTRIDGE HEATERS—Before leaving the subject of wire-wound heaters, mention should be made of the cartridge type. These are small cylindrical heaters made in a variety of sizes and ratings and intended for insertion in pockets or housings especially provided in dies and moulds, and in such appliances as wrapping machines. Their construction permits rapid replacement in the event of failure, or interchange in appliances where the heating requirements vary from time to time. They are not intended for direct immersion in liquids and should not be used in this way.

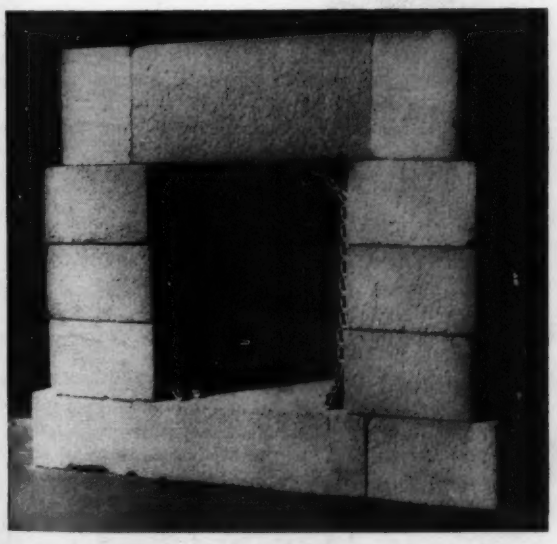


Fig. 11. Portable electric furnace employing a ceramic-bead flexible element by Electrothermal Engineering Ltd.

Fig. 12. A relatively recent introduction, Hunting Mhoglas non-metallic heating mat is shown here in typical applications: (left) a heating muff and (right) a heated elbow.

INFRA-RED HEATERS—Infra-red radiation has greater powers of penetration than normal radiant heat and is for this reason a very effective means of drying or curing unexposed materials; for example, glues or bonding resins. The element most commonly used is in the form of a tungsten filament sheathed in silica or metal, but a simpler form resembles an ordinary incandescent lamp.

"DIRECT" HEATING—All the above methods of heating are indirect, i.e., the heat is developed in an element and conveyed to the work by conduction, convection or radiation, or by a combination of these. There are, however, methods of direct electrical heating, in which the current passes through the work itself:

Resistive heating is performed by passing a large current of low voltage and frequency through the work, which must, of course, be an electrical conductor. The method is highly efficient, but great care is required to ensure that the electrical connections are maintained in good condition, due to the large currents involved.

The arc is mainly used for melting large quantities of metals or ores by immersing one or more electrodes, usually of carbon, in the material, and generating a high-power arc between the electrodes or between one electrode and the material. This method permits powers of thousands of kilowatts to be developed efficiently in a small space, but is confined to materials that can tolerate extremely high local temperatures.

Dielectric heating is a process for the uniform heating of non-conducting materials. The material to be heated is sandwiched between two metal plates to which a high-frequency alternating voltage (from 2-200 Mc/s.) is applied. The high-frequency current causes molecular disturbance within the material and consequent generation of heat.

Established industrial applications of dielectric heating include the preheating of phenol-formaldehyde powder during the manufacture of thermosetting plastics, the welding of thermoplastics and the rapid hardening of synthetic resin glues in the woodworking industry.

Induction heating, used mainly for ferrous metals,

Fig. 13 (Left). Heatrae 180-kW. grouped immersion heater

Fig. 14 (Above). Isojacket cylindrical surface heater with screwed fixing arrangement

utilises currents induced in the work from alternating currents flowing in a coil or coils surrounding it.

By judicious selection of the optimum supply frequency, the temperature, rate of heating and degree of penetration can be controlled within fine limits, and the method is therefore finding increasing application in the heat treatment of ferrous metals. Frequencies of from 1 Kc/s. to 1 Mc/s. are in general use, and require specially constructed generators. However, active development is in progress with heaters fed direct from the 50-cycle mains.

Frequently with process vessels, vats, etc., a combination of induction and resistance heating is employed; in addition to the induction heater coils surrounding the vessel, a conventional resistance heating pad is applied to the base. This arrangement facilitates control of the heat input and improves the overall power factor of the installation.

Mains frequency induction heating is now being used successfully in the construction of quite large melting furnaces, and six-ton versions by Birlec Ltd. are in regular use. This type of furnace permits close control of temperature and composition, and the stirring effect, which is a feature of induction heating, helps to mix added constituents. Naturally an installation of this size (its rating is 1,100 kW.) lacks the simplicity of the more modest mains-frequency heaters mentioned above; among other things, a substantial transformer/capacitor station is necessary to ensure efficient supply and control of the current.

Of particular interest is a dual-frequency installation (also by Birlec) used for the heat treatment of forging billets. The billets are preheated to 700 deg. C. in a mains-frequency furnace, and are then passed through a heat-insulated tunnel to a 3-Kc/s. furnace which raises them to forging temperature. This dual process has the effect of halving the high-frequency generator requirements, and the rapid heating reduces scale formation to a minimum.

Selection for Special Duties

The particular applications of the various types of element and heater have already been touched upon, and Table 1 is therefore in the nature of a summary. With such a vast number of possible applications it is impracticable to include more than a representative selection, which should, however, serve as a general guide.

Calculation of Wattage Loading Required

In every heating application a certain amount of heat is inevitably lost, dependent upon the efficiency of the thermal insulation and the temperature difference between the work and the surrounding air. A fully-lagged storage tank fitted with an immersion heater is extremely efficient; with a temperature difference of 100 deg. F., the losses vary from about 0·5 kWh. loss per gallon (water) in 24 hours for the smaller sizes to a mere 0·1 kWh. per 24 hours for a 30-gal. tank. Once these losses have been computed for the particular installation, they must if necessary be added to the requirements for the job itself. Taking as an example this method of heating liquids, the power required is given by

$$\text{kW.} = \frac{\text{Gal.} \times \text{Temp. Diff.} \times \text{Specific Heat} \times \text{Specific Gravity}}{\text{Time (hours)} \times 341 \times \text{efficiency of heater}}$$

For example, the power required to heat 100 gallons of an oil of specific gravity 0·9 and specific heat 0·5 from 60-160 deg. F. in 1 hour would be

$$\frac{100 \times 100 \times 0{\cdot}9 \times 0{\cdot}5}{1 \times 341 \times 0{\cdot}9} = 15 \text{ kW. approx.}$$

(assuming a heater efficiency of 90 per cent).

In a fully lagged tank of this capacity the loss over the period would be negligible as a factor affecting the speed of heating and could be ignored, but to maintain the temperature in the face of even this small loss it would be necessary to provide a standby element of capacity just large enough to counteract the loss, or to arrange for cyclic switching; for example, with a thermostat. This method has the disadvantage that the temperature does not remain truly constant, but varies between the cut-in and cut-out temperatures.

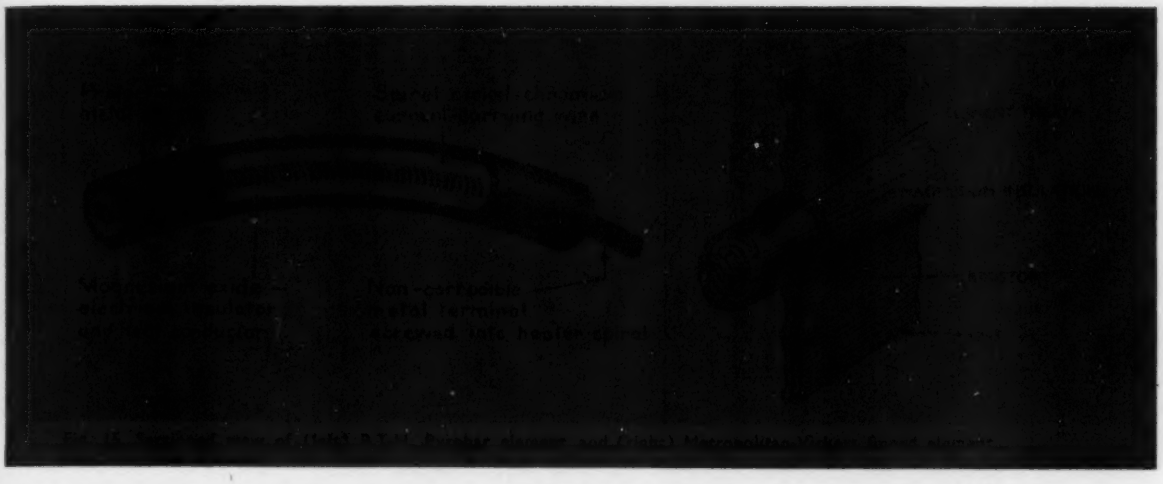
When dealing with a gas or liquid flowing through a pipe or duct it is, of course, necessary to take into account the rate of flow. As a typical example, the loading for air flowing through a duct is given by

$$\frac{\text{Temp. rise} \times \text{cu. ft./h.} \times 0{\cdot}2}{3{,}400}$$

For gases other than air, the relative specific heat and specific gravity must be allowed for.

Surface Loading—Rapid destruction of the heating element will occur if the heat generated is not carried away sufficiently quickly, and for this reason the surface loading, i.e., watts per unit area of the heating surface of the element, must be related to the nature of the surroundings. The graph (Fig. 6) indicates the element sheath temperatures at different surface loadings ("specific load") in water, oil and still air for a typical tubular heater.

Continuous movement of the surrounding medium, whether air, gas or liquid, will help to keep down the element temperature and thus permit higher surface load-



ings; this can be taken into account when the heating of air, gas or liquid flowing through a pipe or duct is being considered. Similarly, in a furnace, the more rapidly the heated material is taken away and replaced by cold, the greater is the exchange of heat. A continuous throughput therefore prevents undue rise in temperature and permits higher surface loading.

Design of Simple Elements

Although with the wide variety of ready-made heating elements available on the market it is seldom necessary for a heater to be made up specially from basic materials, this need does sometimes arise, and a brief account of the principles involved in the design and construction of a simple wire-wound element may be of value.

The size (i.e., cross-sectional area) of the wire employed is determined in relation to the current (amperage) that will be flowing through it in service; the length of wire required will depend upon the supply voltage. The product of voltage and amperage gives the wattage, which is the amount of heat produced (not to be confused with the *temperature* of the element). Once the basic requirements have been determined, manufacturer's tables for the material must be consulted; these will provide the necessary data on maximum current-carrying capacity (governing wattage and temperature) and specific resistance (governing the length of wire to be used).

For example, to determine the length of wire required

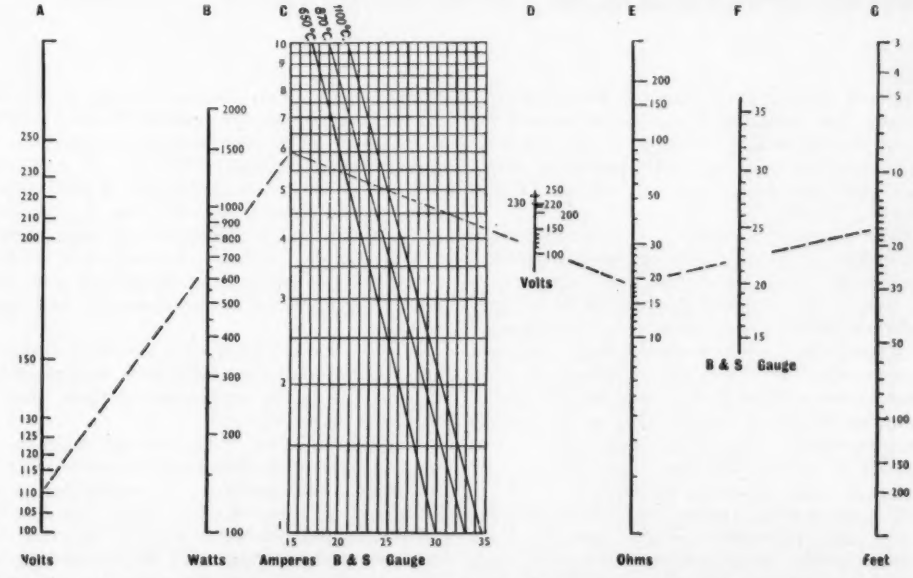


Fig. 16. Nomogram for calculating approximate length of 80/20 nickel-chromium heating element using Nichrome V.

Example:

To design an element for 660 watts, 110 volts, to operate at 870 deg. C:

1. A straight edge laid from 110 volts to 660 watts, gives 6 amps. on scale "C".
2. A horizontal line from 6 amps. to 870 deg. C. intersects the vertical line at 22 B. & S. gauge on B. & S. scale.
3. A straight line from 6 amps. on scale "C" to 110 volts on scale "D" intersects scale "E" at 18 ohms.
4. A straight line from 18 ohms to 22 B. & S. gauge on scale "F" intersects 17 ft. on scale "G".

The element required is therefore 17 ft. of 22 B. & S. gauge wire.

Note: Allowance has been made for the increase of resistance with temperature.

(Nomogram by courtesy British Driver-Harris Co. Ltd.)

for a 1,000-watt heater to operate on 230 volts, first calculate the current:

$$\text{Current} = \frac{\text{watts}}{\text{voltage}} = \frac{1{,}000}{230} = 4{\cdot}35 \text{ amp.}$$

The manufacturer's tables for a typical nickel/chrome alloy (Nicralloy) quote B. & S. 23 (0·0226 in. dia.) as the most suitable gauge of wire for this current. The element working temperature, incidentally, will be 1,000 deg. C.

The resistance of the required length of wire is

$$\text{Resistance} = \frac{\text{voltage}}{\text{current}} = \frac{230}{4{\cdot}35} = 52 \text{ ohms.}$$

The specific resistance of B. & S. 23 wire at 1,000 deg. C. is 1·322 ohms per foot. The length of this required is therefore

$$\frac{\text{Resistance}}{\text{Specific resistance}} = \frac{52}{1{\cdot}322} = 39{\cdot}3 \text{ ft.}$$

This wire is now wound on to an insulating and heat-resisting former or refractory of a shape and size suited to the particular application. In the example quoted, straight winding would result in a large heater of low heat density; greater concentration of heat would be achieved by first winding the wire into a helical coil of, say, ¼-in. diameter. A straight section should, however, be left at each end, as it is desirable to have the terminal connections as cool as possible. On finally winding the helical coil on to the former or refractory, care must be taken that the turns of the helix are equally spaced throughout the length of the element; turns which are too close together will produce hot spots leading to premature failure.

REFERENCE

1. *Engineering Materials and Design*. "Special Glass Windows for High- and Low-temperature Conditions", June 1959, 316-8.

PRINCIPAL U.K. MANUFACTURERS

Geo. Bray & Co. Ltd.
Backer Electric Co. Ltd.
H. A. Birch & Co. Ltd.
British Resistor Co. Ltd.
British Thomson-Houston Co. Ltd.
Cressall Manufacturing Co. Ltd.
Electric Elements (Willenhall) Ltd.
Electrothermal Engineering Ltd.
Eltron (London) Ltd.
Genristo Ltd.
Heatrae Ltd.
Hedin Ltd.
Hunting Mhoglass Ltd.
Isopad Ltd.
Metropolitan-Vickers Electrical Co. Ltd.
Morgan Crucible Co. Ltd.
D. Napier & Son Ltd.
P. & R. Electrical (London) Ltd.
Stabilag Co. Ltd.
Tetra Engineering Co. Ltd.
Thermal Syndicate Ltd.

We acknowledge with thanks the co-operation given by the above companies in the preparation of this survey.

PROTECTING MOLYBDENUM FROM OXIDATION

A NUMBER of coatings are available for protecting molybdenum from oxidation at elevated temperatures; coatings based on chromium, silicon, nickel, precious metals, ceramic materials and refractory oxides are foremost among those that have been investigated by the Battelle Memorial Institute.

Although there is no perfect coating for unconditionally protecting molybdenum from oxidation, several systems have been developed to give satisfactory and reliable protection for a number of conditions that may be met in use.

It is unfortunate that in many instances as the temperature of the system rises, other environmental conditions also become more severe. For example, in turbojet engines, increased temperature is accompanied by increased velocity and, hence, increased parameters for erosive and impact effects by foreign particles. More often than not, selection of a coating system is equally dependent upon qualities of oxidation resistance and mechanical properties.

Methods of application of coatings often determine the quality and protective capabilities of the coating, and the usual methods include electro-plating, flame spraying, vapour deposition, cladding, enamelling and liquid-phase diffusion. The behaviour of inherently porous electro-deposited coatings may be improved by the application of duplex layers. Among the most promising electro-deposited coatings is chromium plated with nickel, although these coatings do not offer a very high resistance to thermal cycling.

Chromium coatings are readily compatible, possess fair thermal expansivity match with molybdenum and are moderately oxidation-resistant, brittleness being the major problem. Chromium coatings resulting from a liquid-phase cementation process are reported to be promising.

Although nickel and nickel-base alloys do not have a good thermal expansivity match with molybdenum, they possess the compensating features of good oxidation resistance at temperatures to 1,100 deg. C., compatibility with molybdenum and excellent ductility and strength of bond.

Molybdenum disilicide coatings are characterised by excellent time-temperature capabilities and good thermal expansion match with molybdenum, but are inherently brittle.

Precious metal coatings are inherently resistant to oxidation, ductile and compatible with molybdenum, and their thermal expansion coefficients compare quite favourably with that of molybdenum.

Ceramic or glass base coatings may be matched to molybdenum to provide excellent thermal expansion characteristics. The addition of crystalline solids such as chromium and zirconia have been found to improve the adherence and protective qualities of glass coatings. Refractory oxide coatings may be matched to molybdenum for good thermal expansion characteristics and these coatings are characterised by high hot hardness, brittleness and relatively low thermal conductivity.

Clad coatings are uniform and continuous, but special precautions are necessary to preserve continuity at sheared edges and joints. Limitations common to vitreous enamelling regarding uniformity of coating at corners or in recesses apply equally to coatings on molybdenum. Liquid-phase diffusion processes have been investigated, but usually are not so practical as other methods.

designer's notebook

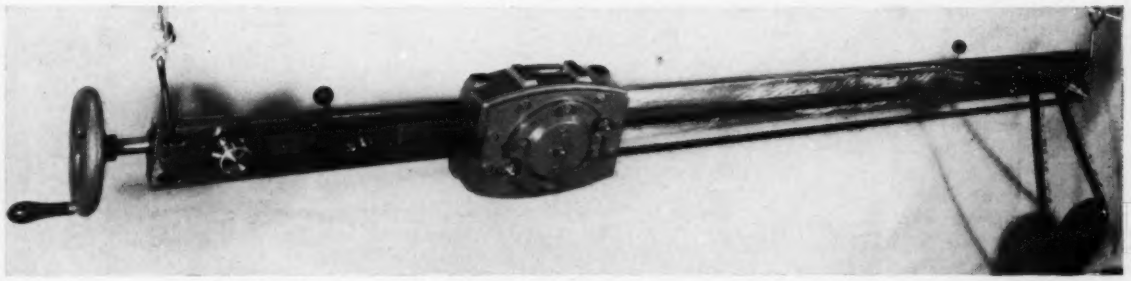
Reversal of Motion Effected by a Chain Drive

IT is sometimes necessary to incorporate in a machine a continuously reciprocating part. The mechanism illustrated shows a type of chain reversing gear which can be used, for example, for altering the direction of motion of a spray nozzle in coating sheet metal. (This is made by Arnold & Stolzenberg G.m.b.H.)

The advantage of such reversing gears is that they make possible a reversal of rotary or reciprocating motion with positive guided control. The number of changes in direction can be adapted for individual requirements, the time lapses remain the same and the instant of reversal can be defined precisely.

The Arnold system, however, is by no means restricted to the example shown in the photograph, and schematic drawings showing the working principle are given below. In Fig. 1 a roller chain of standard design (1) connects the drive wheel (2) and the driven wheel (4). In order to equalise the changes in length which occur during the reversing process, the chain passes over idlers which are under spring loading. Near the drive wheel it is guided in a positive manner by two curved track cam plates (3) of the reversing mechanism. A link pin chain stud is fixed into the chain, i.e., a connecting piece, rigid or articulated which is attached to the sides of the end links of the standard chain by means of lengthened and strengthened link pins. The lengthened knuckle pins of the connecting pieces have guide rollers on their sides which, by engaging with the curved track cam plates, bring about the reversal of motion. At the instant of reversal the chain winds on to the drive wheel in a reversed direction. The direction of the rotation of the drive wheel is altered to correspond with the reversal.

A very short reversal period (short effective chain length) can be obtained by fitting a second connecting piece into the arrangement shown in Fig. 1. Fig. 2 shows how a larger, effective chain length can be used.



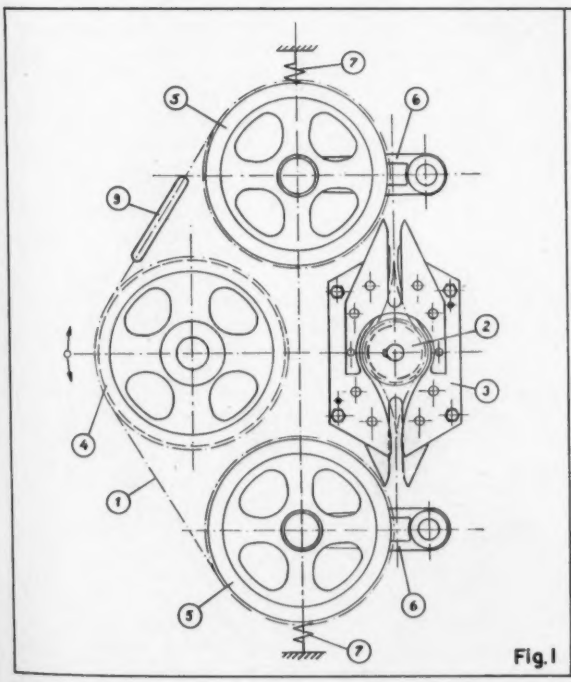


Fig. 1

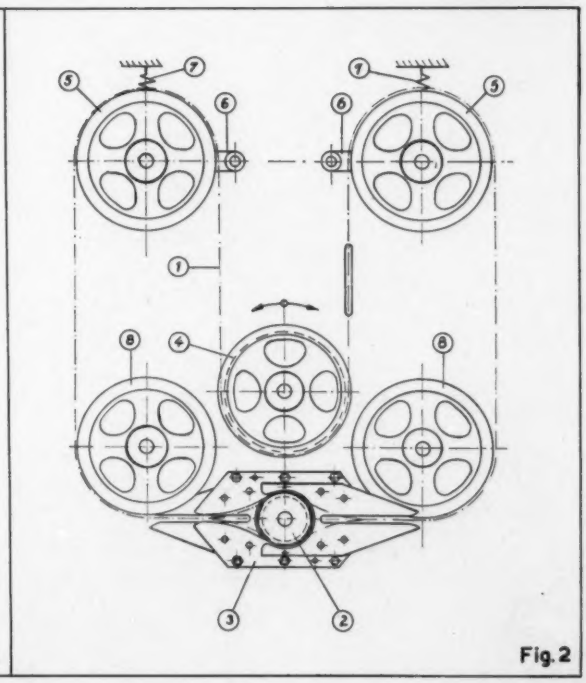


Fig. 2

PROBLEMS IN DESIGN

THE problem in our October issue, i.e., "to provide a means whereby a rotating shaft could be made to reciprocate a shaft at right angles, both about its axis and also lengthwise", brought a large number of ingenious entries. As we gave no exact information as to the extent of the angular reciprocation required or whether this should be in step with or out of phase with the axial reciprocation, the entries were very varied in nature. Taken as a whole, all types of contingency were catered for. First, there were simple linkages which could provide small angular reciprocation only, in step with axial reciprocation. Secondly, there were rack and pinion mechanisms giving greater angular reciprocation but still in step with the axial movement. Thirdly, a number of entries, by the introduction of gears, made it possible to separate the two kinds of output motion and achieve out-of-step movements.

In the first category we consider that, for sheer simplicity, Mr. D. Codd's solution is the best (Fig. 1). If it were manufactured, it might perhaps be improved (see inset) by the use of the ball-end bearing commercially available, in the bore of which the crank pin on the input shaft would slide. (The same comment applies to the two solutions submitted by Mr. W. B. B. Chalmers (Fig. 5).

In the second category, Mr. H. Tooby, A.M.I.Mech.E. (Fig. 2), and Mr. T. Prendergast, B.Sc., A.M.I.Mech.E., sent almost identical entries using a rack mechanism which would be capable of providing a larger angular reciprocation with a sinusoidal axial movement at the same frequency.

In the third category two ingenious entries were received. Skew gears, whose ratios could be varied to suit the application, were used by H. Owen (Fig. 4) in conjunction with linkages which would provide for cases where the two movements were out of step, while W. B. B. Chalmers (Fig. 5) rightly drew attention to our lack of precision in formulating the problem and presented two solutions, one of which was similar to Mr. Codd's solution, the other having the two movements effected by separate space cranks, the drive shafts of which are geared together. In this way different frequencies for the two movements could be achieved.

Fig. 1.

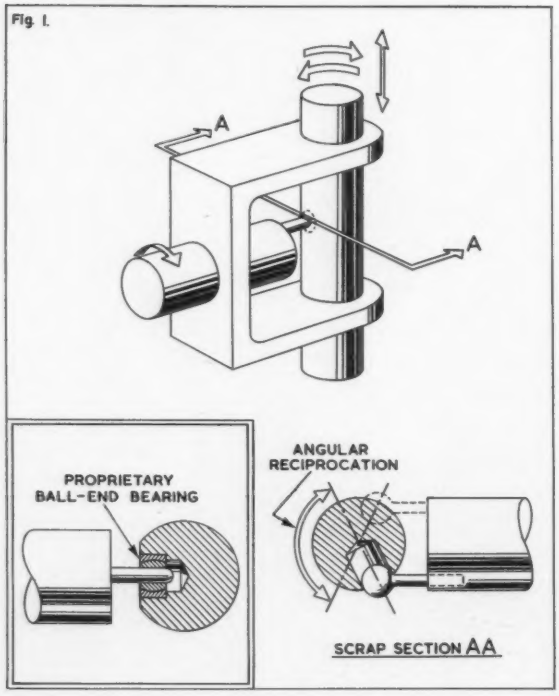


Fig. 2.

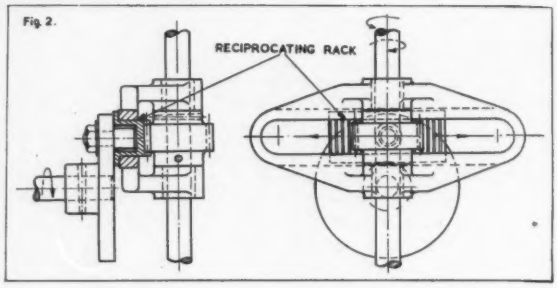
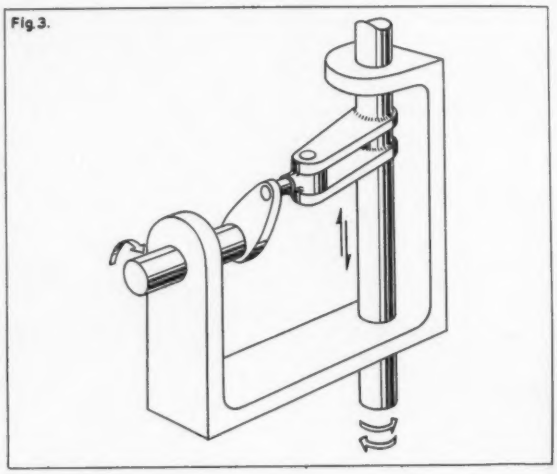


Fig. 3.



A simple solution we consider reasonably elegant, coming in the first category, is given in Fig. 3.

Sorting out the many entries presented us with quite a problem. A number of them contained long-pitch helices, while others employed amazing gear arrangements of great ingenuity but containing, in our view, "too many wheels" to achieve the simple result required. A notably common and poor feature of a number of entries was the use of round shafts sliding on flat surfaces which, if used, would make for friction and wear. Our reaction to the quality of the entries as a whole was that, in all but a very few cases, they underlined the fact that there is a lack of appreciation of space linkages in this country. To appreciate movement problems in three dimensions, it is essential that the designer be able to think "in the round" and for the exercise of this faculty he should do his sketching, in the first instance, in perspective. Too many otherwise excellent draughtsmen cannot do even very simple perspective drawing. Too many want to

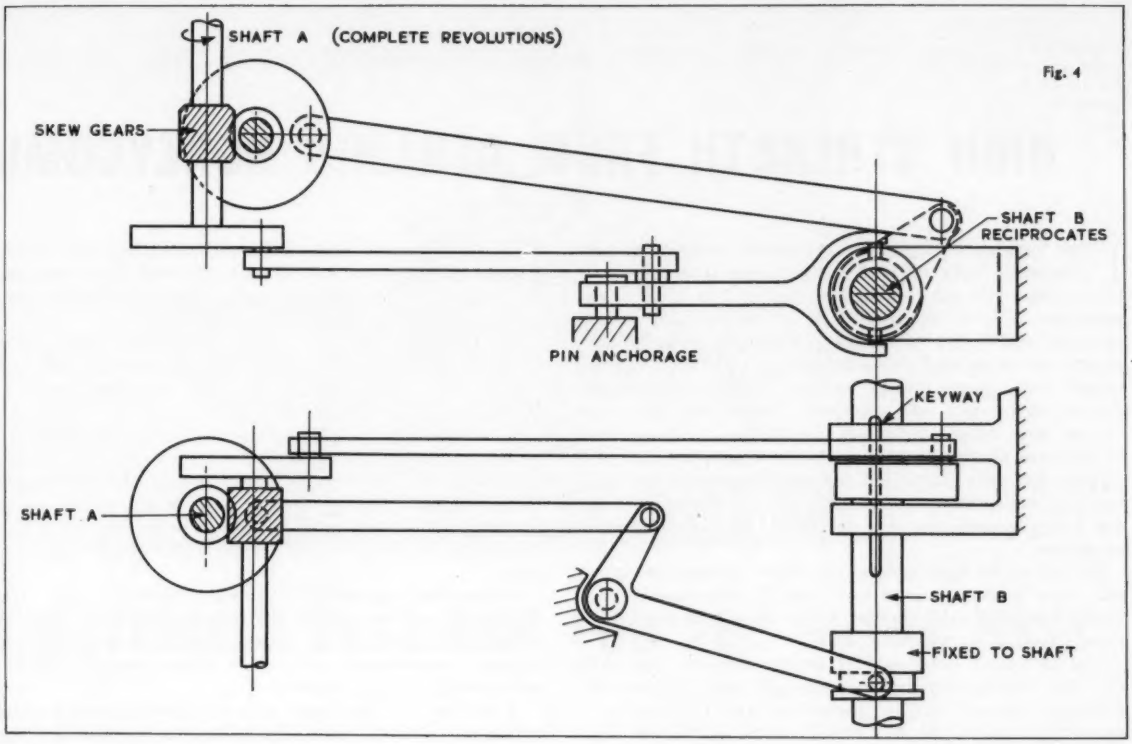


Fig. 4

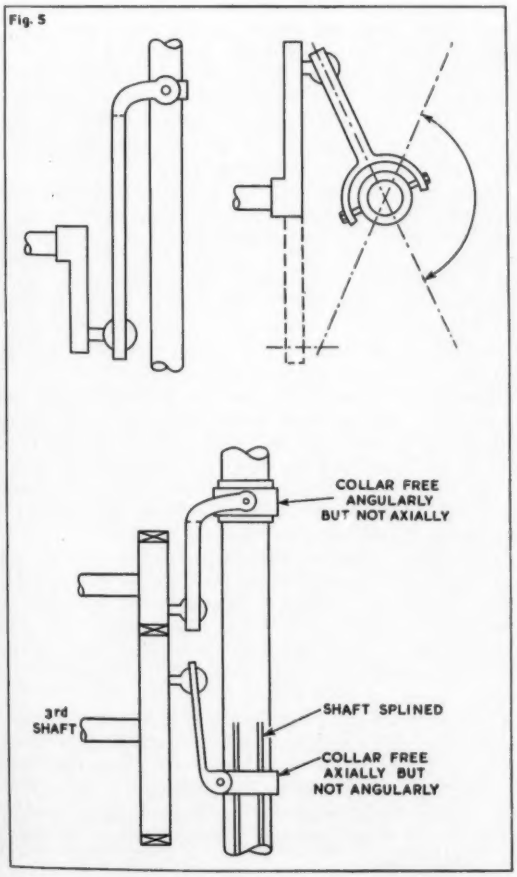
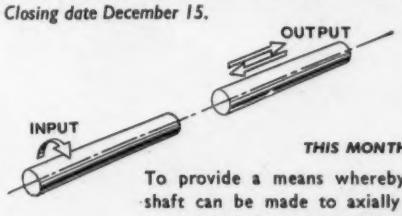


Fig. 5

start right away with the T square or draughting machine and "see what it looks like on the board", laboriously projecting from one view to another to ascertain if one component interferes with another. It is not surprising that some of the most fundamental mechanisms were developed originally by mechanic inventors of the last century who had little or no knowledge of engineering drawing. They thought in three dimensions straight away.

When the paper "Link Mechanisms in Modern Kinematics" was presented to the Institution of Mechanical Engineers in 1953 by the late Paul Grodzinski and Professor Ewen M'Ewen, among the communications received was one from Prof. F. G. Altmann, of Brunswick, in which this point was stressed. Both the paper and the communications are most informative and contain numerous examples and references. We feel that it should be compulsory reading for all those engaged in the design of both plane and space linkages.

Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a diagram if necessary, to The Editor, E.M. & D., marked "Problems in Design (December)". Closing date December 15.



THIS MONTH'S PROBLEM

To provide a means whereby a rotating shaft can be made to axially reciprocate a second shaft, coaxial with the first, one revolution of the input shaft causing one complete reciprocation, without the use of cams, springs or gears.

HIGH STRENGTH FROM CERAMIC HONEYCOMB

FOR high-speed flight, the materials engineer is hard pressed to keep up with the designer, since the structural substances must withstand higher and higher temperatures. This is especially true of aircraft nose cones, radomes and aerial "windows". Although ceramics have been used on smaller air-to-air and ground-to-air missiles, certain basic shortcomings, such as weight, difficult production techniques and electronic limitations, have prevented wide usage. Two U.S. companies, Corning Glass Works and Minnesota Mining & Manufacturing Co., have already this year introduced ceramic honeycomb materials, but a recent technique developed by the Boeing Airplane Co. may, however, solve a number of its own specialised problems.

Proved to be light and strong, these ceramic structures will resist temperatures of 1,650 deg. C. and more and will stand up against rain erosion. At the same time they can be mass produced economically.

The technique developed at Boeing employs thin skins and thin corrugations of high strength, high temperature-resistant ceramic oxides, permitting the fabrication of ceramic structures similar to metal or plastics honeycomb-sandwich panels. Panels for nose cones and radomes which employ compound curves can be formed of ceramic honeycomb on a production basis.

Although much of the development work was done with sintered alumina, other ceramic oxides, such as spinel, mullite or fused silica, are proving equally good.

Claimed to be unique, the Boeing honeycomb consists of non-plastic, pure oxide materials finely ground and combined with suitable organic binders and either organic or inorganic liquids to form a paste. This material is rolled under heat into thin, dense sheets which have properties similar to paper and which are flexible enough to allow sharp bends. The core is shaped by corrugated rolls.

The sheets are sufficiently rigid to retain any given shape. The various components are moistened with a thin mixture of the same composition to bond them together. When dry, the assembly is strong enough to allow considerable cutting and forming.

Brazing a metal skin to a ceramic honeycomb core by means of flame spraying. The resultant material has a very good strength/weight ratio.

After being fired in a furnace, the ceramic honeycomb assembly emerges as a strong, light, self-bonded unit with a high strength-to-weight ratio and with the electronic advantages of a sandwich structure.

The latter is of particular importance in designing radomes. In the past, solid ceramic radomes demanded a wall thickness equal exactly to one-half the wavelength of the transmitted signal. Otherwise, much of the signal power would be absorbed by the radome material. This requirement limited radar frequencies which could be used.

Honeycomb - sandwich radomes, however, are less limited in that they allow the use of a broader band of frequencies. As a result, it may be possible to achieve efficient transmission of power from several different aerials with a single radome.

A number of other types of honeycomb-sandwich panel structures have been developed which may find application in heat-resistant leading edges, nose cones and skins for hypersonic vehicles.

One honeycomb-sandwich is made from ceramic fibres. These short fibres are similar to the wood pulp used in paper making. Since the fibres are bonded at each end only, the finished sandwich is extremely flexible. Although less heat resistant than other types of ceramic honeycomb panels, this type has excellent thermal-shock resistance. The insulating properties can be enhanced by filling the cells with low-density insulating material.

In an effort to find ceramic materials with low curing temperatures, a phosphate-bonded aluminium oxide has been developed. The curing temperature is only just under 400 deg. C., and this is an important factor in establishing a production programme. Chromium oxide can be added for more strength. To improve resistance to impact and thermal shock, molybdenum wires or screen can be embedded in the mixture during the rolling of the sheet and prior to making the honeycomb core.

Honeycomb panels may also be made of metal skins brazed to a ceramic core which has been flame sprayed with metal. In this case, the coefficient of thermal expansion of the metal and the ceramic core must be matched so that the bond will not be pulled apart with changing temperature. Thermal conductivity can be reduced by evacuating the air from within the panel.

At present, honeycomb-sandwich panels can be made from materials such as aluminium oxide and zirconium oxide which will withstand temperatures to 1,400 and 1,900 deg. C. respectively. Work is being done with oxides and carbides of such elements as hafnium and thorium, which will withstand temperatures in the 2,200 to 2,600 deg. C. range, or even higher.

Ceramic materials are under study which have extremely low or even zero coefficients of thermal expansion. Honeycomb-sandwich panels made from such materials would be completely unaffected by rapid changes in temperature. Still another development is the formation of laminated structures by flame spraying alternate layers of ceramics and molybdenum.

Fast patrol boat by Vosper Ltd. Hull built from welded aluminium members plated with glass-fibre sheathed mahogany below the water-line. Engine air intakes of glass fibre.

MATERIALS RESEARCH FOR THE ROYAL NAVY

The Admiralty Materials Laboratory and the Central Dockyard Laboratory, are devoted to the study and development of materials that are vital to the future of naval fighting equipment

A LABORATORY for the study of materials for naval use has existed in Portsmouth Dockyard for nearly a hundred years, but it was the experience gained in the two world wars that emphasised the need to broaden and intensify studies in this field. These are now carried out by the Admiralty Materials Laboratory at Wareham and the Central Dockyard Laboratory at Portsmouth.

Both these laboratories are staffed by chemists, metallurgists and chemical engineers, often working in conjunction with other branches of the Royal Naval Scientific Service. The major work of the two establishments lies in materials research and development that make possible extensive developments in naval equipment and weapons.

The greatest individual problem which concerns both the A.M.L. and the C.D.L. is corrosion (which can cost the Navy millions of pounds sterling a year) and fouling (which can affect a ship's speed by as much as 50 per cent after six months). Research into anti-fouling involves long-term investigation of the habits of marine life; at present, the cheapest and best method of protection is by the application of special toxic paints developed in the C.D.L., enabling ships to remain at sea for up to two years before needing attention. This is particularly important for the Royal Navy, because ships may have to wait for long periods in highly-polluted waters near ports. This encourages sea growth, since settlement of fouling organisms does not take place at speeds in excess of two-and-a-half knots. Alternative methods, such as the use of ultrasonics, are also being investigated.

Investigation of cathodic protection, not only of hulls but also of shore installations and pipelines, has led to the development of new zinc-based alloys for galvanic anodes, and a new lead-based alloy for use with impressed current, details of which have been placed in the hands of industry. The use of cathodic protection has introduced further problems in the compositions of paints and their adhesion, especially with the locally high-current densities associated with the use of impressed currents with certain types of inconsumable anode.

In addition to the antifouling requirement, there is also the need for materials which resist the growth of fungi. This is important not only in living quarters such as galleys and bathrooms, where humidity and temperature are conducive to rapid growth, but also in instruments and operational equipment where serious deterioration could result in failure to operate at a moment's notice.

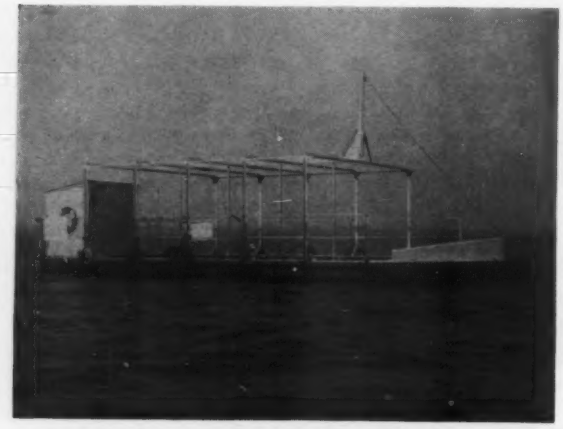
Various types of fungi are classified and their effect and rate of reproduction are carefully recorded. The development of fungi-resistant surfaces is of the utmost importance, since spores of the fungi floating in the air will, if sufficiently concentrated, affect the mucous membrane.

In the general chemistry division of the A.M.L., fundamental and applied research is carried out on a variety of subjects. One example of this work is the development of methods of the analysis of various materials such as semiconductors, where the presence of impurities at concentrations as low as one part in 10^{10} are significant. Neutron activation analysis, emission spectrography and ultraviolet spectrofluorimetry are some of the techniques used, and many of the instruments are designed and made by the scientific staff to fulfil the particular requirements. In many cases the information obtained has been shared with industry, which thus benefits by the work done primarily for naval requirements. Another example is the development of ceramic materials having special electrical or magnetic properties, such as are required for radar equipment or underwater detection devices.

Hydrogen peroxide (H.T.P.) is now accepted by the R.N. in underwater propulsion systems, for which it has considerable advantages. Studies of the physical and chemical behaviour of hydrogen peroxide and the development of improved decomposition catalysts, as well as ad-

vising on the safe handling of H.T.P., are aspects of the work carried out.

Rubber and plastics naturally figure among the activities of A.M.L., which has an experimental compounding unit for rubber and plastics as well as laboratories for the evaluation of these materials. They are equipped to cover a wide range of investigations into the chemical, mechanical and electrical behaviour of these materials, including extensive facilities for evaluating physical properties under dynamic conditions. On the fundamental side there are facilities for the determination of chemical constitution by infra-red spectroscopy and molecular weight by light scattering and osmotic pressure techniques. The responsibilities of this division range from the development of special compositions to meet specific naval requirements to the provision of design information and advice to Admiralty Ship and Weapons Departments on the ever-increasing variety of polymeric materials.



One of three Admiralty exposure rafts used for testing underwater paint systems and other materials.

Part of one of the rubber and plastics laboratories at A.M.L., showing compounding machines.

Gritblasting a ship's hull using Vacu-blast equipment fitted to the boom of a Simon platform.

The chemical engineering division is making important contributions to the design of condensers, evaporators and boilers. Treatments for scale prevention in evaporators have been developed, and methods for improving heat transfer, including the application of dropwise promotion techniques, are being studied. From the immense amount of work carried out a new approach to the design of plant has resulted, and this is leading to greater efficiency and space saving.

The metallurgical division devotes the greater proportion of its present activities to investigation of suitable materials for nuclear propulsion, and its highly qualified staff have been responsible for a number of new alloys of interest to industry, ranging from zirconium alloys for nuclear applications to special alloys for lead-acid battery grids. Irradiation effects on steels are being studied and techniques to simulate irradiation damage are being developed. Batteries of creep-testing equipment, designed to operate both in vacuo and in air, are determining the long-term properties of new alloys under various conditions of temperature and stress.

Not only is it necessary to evaluate the physical properties of a material, but also it is of the greatest importance to ascertain its behaviour under operational conditions and its repairability. Titanium propellers may be quoted as an example[1]: not only must the material have adequate strength and stiffness, but it must have the necessary resistance to corrosion and cavitation erosion, be sufficiently ductile to withstand shock and impact loads arising from drifting matter and, in the event of a breakage, be easily repaired. Thus it will be seen that before a component enters into service it must not only fulfil all the previously mentioned conditions, but must also show its superiority under service conditions. These service conditions can to some degree be simulated in the laboratories by the use of special rigs and equipment.

A recent contribution to industry, and one that may become of immense importance, is the development of a ceramic, based on silicon nitride, possessing unique mechanical properties at high temperature.

The C.D.L. dates from about 1870, when it was concerned with materials which in those days consisted of little more than timber, brasses and iron. Today its functions are, as previously mentioned, primarily day-to-day problems of the Royal Navy, and short-term and applied research, excepting investigations into antifouling which also has been a long-term research policy because of its immense importance. It is the parent laboratory of other dockyard laboratories at Chatham, Devonport, Rosyth and Singapore.

The basic problems are those concerned with protective and antifouling paints, corrosion and cathodic protection, general and miscellaneous materials research and gases.

While the C.D.L. does not have perhaps the glamour of the long-term researches conducted by the A.M.L., it does carry enormous responsibilities. Typical of these are the checking of fuel storage tanks and their inspection for vapour before allowing work to be commenced. Further responsibilities cover such things as the evaluation of floor and deck covering, batteries and ships' stores, compounds

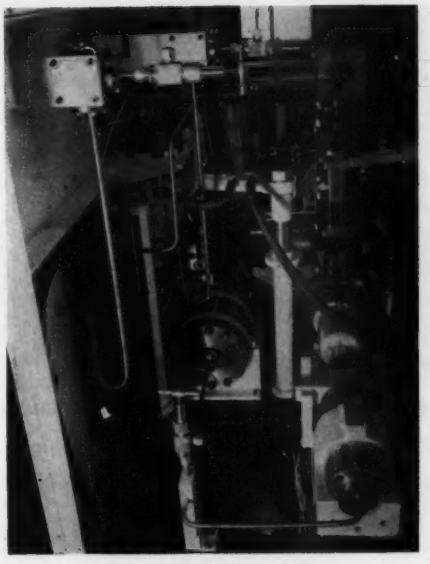
for cleaning, initial evaluation of materials and the investigation of complaints, and of unusual occurrences such as fires and divers fainting.

The work of the metallurgical laboratories of the C.D.L. is highly important in keeping the Navy at the ready. Corrosion problems are by far the most serious, and these in the main are more pronounced in ships laid up, or those which serve as accommodation ships, and current work is directed to the investigation of crevice corrosion which is liable to affect stainless steels and other two-phase materials. Creep cracking in boiler tubes is another subject under investigation. These day-to-day investigations and *ad hoc* tests bring to light shortcomings in materials and components which are then either modified at the C.D.L. or the information passed back to the manufacturers, thus benefiting industry as a whole. A typical example is the investigation into the failure of large steel bearings lined with white metal, which was remedied by the repair of worn shafts by the application of sprayed molybdenum.

Development of Special Alloy

Problems relating to cathodic protection form a large part of the work conducted at the C.D.L. Ships close to shore establishments are often protected by impressed current methods, while those not so conveniently situated may use consumable anodes. Investigations have been made on materials for use as anodes, and these have led to the development of a special zinc alloy which demands either complete elimination of the iron content or an additive which nullifies the effect of the iron. In this problem, two different approaches are possible and were investigated by joint efforts of both the R.N.S.S. and their U.S. counterparts. Their subsequent tests on these new alloys, together with tests on new lead-based alloys, again have been passed to industry for general usage.

With cathodic protection, factors other than the choice of a suitable material have to be considered, and among them are the effect on performance and noise produced by the anode projections on the hull and, where impressed current methods are used, whether it is likely to lead to detection of the ship by enemy craft using Asdic or other detection apparatus.



Special equipment developed at A.M.L. to study corrosion in pressurised-water nuclear reactors.

A further aspect of the work of the C.D.L. is the investigation of processes for the cleaning of ships in dry dock, such as electrolytic descaling, blasting and, more recently, the development of the Vacublast process for applications to ships.

BEHAVIOUR OF METALS SLIDING AT HIGH TEMPERATURES

AMONG the interesting papers delivered at a recent joint conference of the American Society of Lubrication Engineers and the American Society of Mechanical Engineers, one entitled "The Sliding Characteristics of Metals at High Temperatures" underlined the need for reliable data in this field of operations. From tests it has been found that, as the temperature is increased, a large increase in friction and surface damage occurred. This persists until a temperature is reached whereby an oxide film is continually reformed at the sliding surface, at which temperature the sliding characteristics are markedly improved.

With metals such as cobalt and zirconium, sufficient oxide is generated at room temperature to be beneficial, but with other materials an increase in the ambient temperature is necessary to promote sufficient oxide formation. Any temperature effect which tends to remove the oxide, such as softening, as in the case of copper, scaling or sublimation will cause a rise in friction and a similar effect would also be hypothesised for cobalt, where the volume change could disrupt the oxide.

There are a number of ways in which the oxide could be acting; for instance, it could be causing an increase in the hardness of the surface layer of the metal, and it could also be decreasing the effective shear strength of the surface by the formation of a reaction film. This latter explanation would not seem feasible for compounds like nickel or zirconium which form oxides. A fourth possibility, although more remote, is that the loose oxide particles may reduce the friction by rolling between the surfaces.

Results show that considerable benefit can be gained by using alloys which form a soft, continuous type of oxide on the surface; these results are also in agreement with previous experience obtained with alloys which contain a major portion of those elements and which form these soft oxides. For those metals which form the hard oxides, it is hypothesised that oxide is sliding on oxide in much the same way as when two solid pieces of oxide are sliding together.

The materials used in these experiments included iron, nickel, copper, cobalt, chromium, molybdenum, zirconium, carbon steels and various nickel-chromium compositions.

Other papers included "An Investigation of Seal Materials for High-temperature Applications" and "The Evaluation of Gear Materials Scoring at 700 deg. F".

RARE METALS FOR SPECIAL PURPOSES

Complex new problems sometimes call for materials that are not in common use. Here—to bring designers up to date on some uncommon metals—is a review of the potentialities of zirconium, hafnium, vanadium, columbium, tantalum, chromium and rhenium

by J. P. DENNY and L. F. KENDALL, Jr. *

FACED with more and more stringent environmental requirements, engineers and designers are broadening their materials-engineering outlook. Metallic materials formerly dismissed as unthinkable now merit serious consideration.

Seven metals which should be given such consideration are zirconium, hafnium, vanadium, columbium, tantalum, chromium and rhenium. While all are available in at least developmental quantities, the amount of scientific effort which has been expended on these metals varies. Considerable data are available on some, while limited information has been obtained on others, but selected data are presented to permit convenient comparison.

Zirconium

During the past few years, zirconium has made rapid advances primarily from the atomic-reactor programme and the availability of zirconium in quantity which permit designers to exploit its unusual properties in a variety of applications.

This metal, marketed as "commercial-grade zirconium", is actually an alloy, since it contains between 1·0 and 2·5 per cent hafnium, depending on the composition of the ore. Although commercial-grade zirconium is perfectly satisfactory for nearly every application, the nuclear properties of hafnium necessitate its removal if the zirconium is to be used in atomic reactors.

For reactor applications, minor amounts of tin, iron, nickel and chromium are usually added to pure zirconium, these additions enhancing the corrosion resistance in very high-temperature water and simultaneously raising the strength of the metal. Both grades of zirconium and the zirconium-tin alloys are available in standard shapes and forms, i.e., plate, sheet, rod, wire, tube and castings.

The outstanding property of zirconium is its corrosion resistance. Media in which it is especially useful include hydrochloric, nitric, sulphuric and phosphoric acids, hydrogen peroxide, most chlorides and most organic acids. In this respect, it is comparable to titanium, tantalum and the stainless steels. For some applications, zirconium is markedly better than any of these, since it is resistant to both alkaline and acidic media.

Zirconium has a lower density than stainless steel, while its thermal conductivity is about the same. Although zirconium is moderately strong at room temperature, the strength drops rather sharply at elevated temperatures. As Table 2 indicates, however, alloying counteracts this tendency to a considerable extent. At temperatures above about 480 deg. C. zirconium and the alloys must be protected from prolonged exposure to CO, CO_2, SO_2, steam, hydrogen and flue gases. Because of the deleterious effects of nitrogen and oxygen, these metals should not be used in air above 650 deg. C.

Zirconium and its alloys can be fabricated and processed by the standard techniques used for stainless steels and titanium. Hot-working operations must be performed in protective sheaths or atmospheres except for very heavy sections such as ingots and thick plate. In addition to forging, rolling, swaging, drawing and forming, extrusion is useful for producing pipe, tubing and complex sections. Zirconium is also readily formed by powder-metallurgy techniques, and it can be joined by welding under an inert shield or silver brazing in vacuum, special techniques having been developed for joints to dissimilar metals. With sharp, carbide-tipped tools, zirconium is easily machined. Since fine zirconium chips burn vigorously if ignited, accumulation of these around machines should be minimised.

Industrial and engineering applications of zirconium depend on its unusual properties. Its use in boiling-water and pressurised-water reactors seems assured for the foreseeable future, since its nuclear properties and corrosion resistance make it nearly ideal for these applications; furthermore, the recently reduced prices increase the margin of advantage of zirconium over other candidate metals. Lower prices will certainly result in extensive use of zirconium for new chemical-processing equipment and related applications where corrosion problems are severe. Among the devices which have been fabricated of zirconium are heat exchangers, valves, reaction vessels, agitators, fan blades and steam ejectors for use with hydrochloric acid. Other applications include alloys (especially with magnesium and as a deoxidant in steels), getters to remove traces of gaseous contaminants from electron tubes, seals of glass and ceramics to metal, and pyrophorics such as flash bulbs, fireworks and primers for explosives. Potential uses include electrolytic capacitors and rectifiers in place of presently-used tantalum and surgical devices for use in the human body.

* *General Electric Co., U.S.A.*

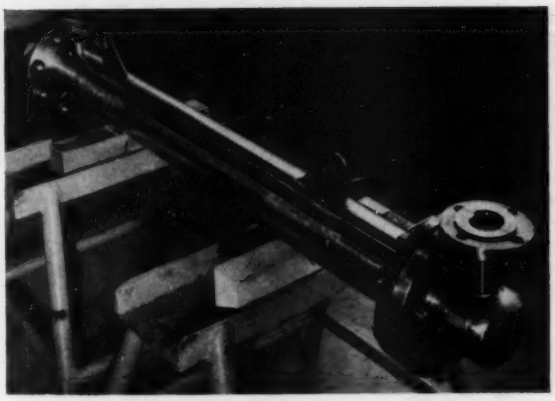
Hafnium

Hafnium recently has become available in practical quantities as a result of the atomic-energy programme to produce zirconium. The two metals are very similar in nearly all their properties.

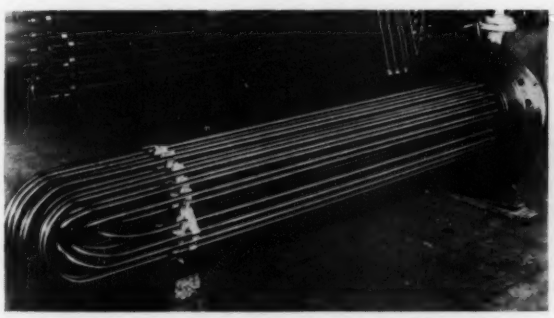
In general, hafnium has the properties of zirconium, except for its absorption of thermal neutrons. Pure zirconium absorbs very few neutrons, so that it is useful for structural components in reactors, whereas hafnium has an unusually high absorption and is useful for controlling reactors by absorbing excess neutrons. Hafnium also has a higher melting point than zirconium, a much higher allotropic transition temperature and nearly twice the density. Like zirconium, hafnium is unusually resistant to many corrosive fluids, but is attacked by air and other gases at elevated temperatures.

When uncontaminated by nitrogen or oxygen, hafnium can be fabricated with nearly the same techniques used for zirconium. It has been forged, rolled, extruded, drawn, machined and welded successfully.

In addition to its application to control of nuclear reactors, hafnium should be useful in applications where the corrosion resistance of zirconium and high transformation temperature are required.



Zirconium used in a heat exchanger built by the Pfaudler Co.



A hairpin heat exchanger by New Metals & Chemicals Ltd. Tubes and tube base are tantalum-clad.

Vanadium

The commercially-purified metal is available in the form of buttons or lumps, and small quantities are being supplied in wrought form for experimental purposes. A typical composition of commercial-grade vanadium is as follows:

V, 99·7	C, 0·03	Fe, 0·04
O, 0·10	N, 0·04	H, 0·008

While prices are relatively high in comparison with many commercial metals, the cost represents a significant reduction from quotations obtained as recently as 1950.

In the hot-rolled and annealed condition, vanadium has a pronounced yield point, and its stress-strain curve accordingly resembles that of mild steel. Its density is 0·22 lb./in.^{3} and its modulus of elasticity is 18-19 $\times$ 10^6 p.s.i. This interesting combination of properties suggests possible future structural applications. Low levels of oxygen, nitrogen and carbon are associated with optimum fracture characteristics.

From the corrosion standpoint, vanadium is resistant to alkaline and hydrochloric acid solutions, but is not resistant to oxidising acids such as nitric. Its resistance to salt water and salt spray may be classed as fair to good. There is evidence that it resists pitting by salt water, but is subject to general corrosive attack.

The electrical resistivity at room temperature is 24·8 microhm-cm., which value is higher than most of the common metals. It is a poor conductor of magnetic flux.

Vanadium does not work-harden rapidly, and may be cold-worked readily. It is a free-cutting material and good machining results have been reported with tool characteristics similar to those used for copper. Remelting and welding operations require protective atmospheres to prevent reaction of the metal with oxygen and nitrogen above 290-320 deg. C. For welds requiring optimum purity, an argon atmosphere is recommended. The material can be hot-worked, and one technique employs an austenitic stainless-steel sheath to protect it from the atmosphere. Fabrication procedures for such composites are similar to those used in the stainless-steel industry.

Vanadium is used as an alloying element in steels, and high-purity vanadium has been rather extensively investigated by the U.S. Atomic Energy Commission, but its value in such applications is uncertain. The metal is currently used as a target in X-ray tubes, but its broader utility as an engineering material presents interesting possibilities. The relatively high electrical resistivity, combined with an intermediate density and modulus of elasticity, merits consideration.

Columbium

The availability of columbium (niobium) has changed from acute shortage to abundant supply.

The bulk of columbium powder is produced to a specification calling for a minimum of 99·5 per cent columbium, with stringent requirements on the quantities of many minor elements. A typical analysis is as follows:

Cb,	99·54	C,	0·047	N,	0·05
O,	0·20	Ta,	0.12	Ti,	0·01
Fe,	0·01	Si,	0.02	B,	0·0001

Columbium powders and granules are now being supplied by several manufacturers, and wrought forms are also available. Sheet, strip, foil, wire, rods and other shapes can be produced by powder metallurgy or arc-melting followed by cold-working. Tubes may be made by forming and welding of strip. Pressed and sintered arc-melting electrodes are also available.

The low thermal neutron capture cross-section of columbium (1·2 barns) makes it attractive for nuclear applications, and it is being used as the canning material for fuels in experimental reactors. It does not work-harden rapidly and can be cold-rolled and formed readily. It is resistant to acid corrosion, although it is inferior to tantalum in this respect. The material has strength at 1,100 deg. C. comparable to that of pure molybdenum, and has an attractive density (0·31 lb./in.^{3}) in comparison with other refractory metals. Columbium is embrittled by nitrogen, and this phenomenon has hampered its ready acceptance as a high-temperature structural material. It is

a superconductor at temperatures below 8 deg. K., having the highest superconducting temperature of any known element with the exception of technetium (11·2 deg. K.).

Most of the procedures for working and fabricating columbium are conventional. It has a tendency to gall during machining and forming, bending, stamping and deep-drawing operations are done at room temperatures to avoid embrittlement resulting from reaction with gases at elevated temperatures. It can be softened by vacuum annealing, with high vacuums to avoid gas contamination. Columbium can be welded to itself by resistance welding and inert-arc welding and a properly made weld is ductile. It may be chemically cleaned with hot chromic acid.

Currently, there are no commercial applications for columbium except as an alloying agent. Considerable experimental work is being directed towards the development of columbium-base alloys for elevated-temperature structural applications as well as nuclear applications. Possibilities also exist for its uses in electrolytic capacitors and in cryotrons for computer application.

Tantalum

Tantalum ores are associated with columbium deposits, and the majority of concentrates come from Africa. Tantalum is potentially in shorter supply than columbium.

A typical commercial tantalum powder has the following composition:

Ta,	99·76	Cb,	0·1	Fe,	0·04
SiO_2	0·02	Na_2O,	0·02	CaO,	0·01
Ti,	0·05				

Such a raw material is suitable for powder-metallurgy fabrication and can be used for high-purity tantalum-carbide production.

Tantalum is available in various forms such as rod, sheet, wire and foil; tubing may be produced by welding.

Tantalum has exceptional resistance to corrosion by acids such as hydrochloric, nitric, sulphuric and phosphoric. It forms anodic oxide films which are of exceptional stability below 300 deg. C. It oxidises readily above this temperature, however, and alloy development or protective coatings will be required for elevated-temperature service in air. It has a low vapour pressure at 2,225 deg. C., being superior to other refractory metals in this respect, with two exceptions (rhenium and tungsten). Tantalum may be welded to itself and certain other metals by resistance welding, while seam-welding is usually done under water to prevent oxidation of the metal. Light welding pressures should be used, since heavy pressures lead to so little resistance across the joint that no weld is made. Tantalum can also be joined by inert-arc welding.

The metal can be annealed by heating in vacuum to above 1,275 deg. C., its recrystallisation temperature. Cold-forming is preferred because of its oxidation characteristics. In lathe operation, high cutting speeds using high-speed tools are preferred as slow speeds will cause the metal to tear. Carbon tetrachloride is recommended as a cutting medium, and the work must be kept flooded at all times. The metal also can be milled, drilled, threaded and tapped. Grinding is difficult.

The most important uses for tantalum are based on its corrosion resistance. It is used in the chemical industries for the processing of such materials as chlorine, hydrochloric acid, chlorides and nitric acid. Applications include heat exchangers, condensers, coils and bayonet heaters. It is similarly immune to body chemicals and has been used for a number of years for implants in the human body.

Tantalum is used in electronic tubes, where its high melting point, low vapour pressure, gettering properties and copious electron emission at reduced power levels are advantageous. Tantalum electrodes are used in electrolytic rectifiers, and tantalum sheet is being employed in capacitors. The oxide film which acts as the dielectric is formed on tantalum by anodic oxidation prior to assembly. The future should see continued usage of tantalum in these and related applications utilising its exceptional corrosion resistance, the good dielectric characteristics of its oxide and other unusual properties.

Chromium

Chromium is well known as an alloying element, electroplated coating, refractory component and as a constituent of various chemicals. The emergence of chromium and chromium-base alloys for structural and other applications, however, is of recent origin.

A typical analysis of commercial chromium lump and powder is as follows:

Cr,	99·45	Al,	0·03	Fe,	0·27
Si,	0·10	C,	0·03	S,	0·02
H,	0·02	O,	0·06		

The primary deterrent to commercial structural application of chromium has been its room-temperature brittleness caused by nitrogen impurites. Carbon is also thought to have deleterious effects. The oxidation resistance of chromium is good at elevated temperatures, but inferior to nickel-chromium alloys.

Because of its reactive nature, chromium must be melted in vacuum or in an inert atmosphere. The molten metal is usually superheated to obtain sufficient fluidity, and casting temperatures are approximately 2,000 deg. C. Prior treatment of the furnace charge at elevated temperatures in pure dry hydrogen removes sufficient gaseous impurities to facilitate the casting process. Resultant ingots are hot-worked by extrusion, forging and swaging. Sheaths are sometimes used to prevent contamination. Powder metallurgy processes also may be used for consolidation.

Development priority has been given to the production and properties of chromium, and only limited work has been done in the joining, forming and machining areas. It recently has been established, however, that brittle cold-worked chromium can often be made ductile by etching

TABLE I. Physical properties of unusual metals

	Zr	Hf	V	Cb	Ta	Cr	Re
Atomic weight	91·22	178·6	50·95	92·91	180·88	52·01	186·31
Density, lb./in.³	0·235	0·472	0·22	0·31	0·60	0·26	0·72
Melting point, °C.	1,860	1,980–2,200	1,730	2,415	2,995	1,888	3,180
Linear coeff. of expansion, per °C.	5·4	6·1	7·7	7·2	6·5	6·1	6·5
Thermal conductivity, B.t.u. sq.ft./hr./in./°F.	118 (at 68°F.)	—	215 (212°F.)	363 (32°F.)	377 (68°F.)	464 (68°F.)	493 (68°F.)
Specific heat, cal./gm./°C.	0·067	0·035	0·120	0·065	0·36	0·11	0·033
Electrical resistivity, microhm-cm. at room temp.	40–45	32	26	13·1	12·4	13	19·5
Modulus of elasticity, tension, p.s.i. × 10^6	13	20	18·5	30·4*	27	36	67

* Subject to confirmation. Values in the literature vary from 12·4–30·4 × 10^6.

away the surface. This may be performed anodically in an orthophosphoric acid-sulphuric acid bath or by direct immersion in hydrochloric-acid solution. The effect is attributed to the removal of heavily nitrided surface layers formed during fabrication.

The potentialities of chromium and chromium-base alloys for structural application are not regarded as good at the present time. Work is continuing in the area, however, and a technical breakthrough is definitely within the realm of possibility. It is considered likely that the initial application of chromium-base alloys will be in other areas such as bearings, tool materials and die materials, wherein high hardnesses developed by surface reactions with nitrogen can be employed advantageously.

Rhenium

That rhenium possesses a combination of unusual properties has been recognised for many years. Only during the past three or four years, however, has the technology been acquired which now promises to make this metal a commercial product in the near future.

Rhenium is difficult to fabricate, but recent work has demonstrated that special techniques can produce bars, strip, foil and wire from the sintered powder. Arc-melted and crystal-bar rhenium, however, can be worked only slightly before failure. Because of hot shortness, rhenium cannot be hot-worked and, instead, must be cold-worked with frequent anneals at about 1,700 deg. C., since cold-working to 30 per cent area reduction triples the hardness of the metal. Despite these difficulties, however, 0·003-in. foil and wire have been fabricated.

The outstanding property of rhenium is its combination of high melting point, low vapour pressure, ductility at room temperature and very high strength.

Among the unusual physical properties of rhenium are its density (the fourth highest among the elements), its melting point, which is second only to graphite and tungsten, and its vapour pressure, which is much lower than that of either tantalum or tungsten.

Tantalum bayonet heater by the Pfaudler Co.

TABLE 2. Mechanical properties of unusual metals

Metal and Test Temp.	Tensile strength, 1,000 p.s.i.	Yield strength (0·2% offset) 1,000 p.s.i.	Elong. %
Zirconium			
Pure, annealed, RT	34	10	47
Commercial, annealed, RT	50	35	35
Commercial, 40% CW, RT	80	70	13
Zircaloy 2			
Annealed, RT	68	45	22
Annealed, 260°C	32	18	36
Hot-rolled, RT	82	66	42
40% CW, RT	108	99	36
Hafnium			
Pure, annealed, RT	59	22	35
Pure, annealed, 260°C	38	12	51
Pure, hot-rolled, RT	79	63	15
Vanadium			
Commercial, annealed	70	63	32
Commercial, hot-rolled, RT	91	—	22
Commercial, hot-rolled, 600°C.	40	—	38
Commercial, hot-rolled, 1,000°C.	7	—	50
Columbium			
Commercial, RT	39	24*	49
Commercial, 550°C.	32	10·5*	24
Tantalum			
Commercial			
Sheet, annealed, RT	50	—	40
Sheet, worked, RT	110	—	1
Wire, annealed, RT	100	—	11
Wire, worked, RT	180	—	1·5
Chromium			
Pure, annealed, 330°C.	41	27	14
Pure, annealed, 1,070°C.	9	9	104
Rhenium			
Pure, annealed, RT	164	135	28
Pure, worked, RT	322	311	2
Pure, worked, 1,070°C.	124	—	1
Pure worked, 1,480°C.	40	—	1

* Proportional limit.
RT = room temperature
CW = cold-worked.

Although it oxidises catastrophically on heating in air, it is very stable in hydrogen or vacuum. Rhenium, unlike tungsten, is not attacked by the "water cycle" which produces failure of tungsten filaments in vacuum tubes by continuously depositing tungsten on the cool tube walls. Rhenium has been shown to be resistant to molten tin, zinc, copper and silver, although it fails in aluminium, nickel and iron. It is also unattacked by aluminium oxide during 7,000 hours at 1,600 deg. C.

Many of the mechanical properties of rhenium are notable, namely, its modulus of elasticity is exceeded only by osmium and iridium, its tensile strength at room temperature is higher than that of tungsten, and it is appreciably ductile at room temperature in contrast to tungsten. At elevated temperatures the ductility of rhenium is poor, although in tensile and creep-rupture properties it is superior to tantalum, columbium and tungsten up to at least 1,370 deg. C.

The principal potential applications of rhenium include electron tubes, and contacts in electrical relays and switches. The use of rhenium in electron tubes is attractive because of its inertness to the "water cycle", its strength and its refractory nature. The applicability of the metal and several binary alloys with tungsten and molybdenum is currently being investigated. Rhenium as a contact metal has already been put to limited use in magnetos for marine engines. In this case, its resistance to corrosion in salt water, combined with its resistance to electrical erosion and its high strength and ductility, make rhenium especially attractive. Its use is indicated for other applications requiring these properties, such as pen points. For measurement of very high temperatures, thermocouples of rhenium with tungsten or molybdenum are usable to about 2,480 deg. C.

This is an abridged version of a paper presented at the A.S.M.E. Design Engineering Conference last year.

MATERIALS FOR FIRE PROTECTION

For sensitive instruments and control gear which must be immune to the effects of fire, some suggestions are made here for materials and methods most satisfactory for their insulation

by C. R. WEBB, Ph.D., B.Sc.(Eng.), A.M.I.Mech.E.*

THE growing use of radioactive materials raises problems in preventing them spreading by vaporisation during an accidental fire. Moreover, interest in the protection of equipment (particularly control equipment), recording film or paper and special apparatus from the effects of fires has also increased in recent times. This subject has been studied for many years by manufacturers of safes, but it is likely that much of the information gained could be of use in engineering, where similar principles could be employed.

It is not uncommon for natural fires to involve temperatures of over 1,000 deg. C. for a period of several hours. At the same time, equipment, paper and film must usually remain at a temperature below 150 deg. C. to avoid damage. Paper becomes dehydrated and brittle at higher temperatures and eventually chars. Contrary to expectation, safety film, if processed under the correct conditions, remains intact and readable after heating to at least 120 deg. C., provided that moisture has been entirely excluded.

In practice, the steel walls of a normal enclosure are reinforced with some material which offers resistance to the passage of heat to the interior. Sometimes a second steel wall is fitted inside the outer wall, and the intervening space is filled with insulating material; otherwise the insulator used is suitable for casting into a box which is externally lined with steel to obtain a durable finish and satisfactory appearance.

Homogeneous Insulation

Many materials are available which possess a low coefficient of thermal conductivity in order to retard the transfer of heat. Such materials are used widely as thermal insulators for ovens, refrigerators, pipes, walls and roofs of buildings, etc. They include cork, wool felt, wood shavings, asbestos, insulating refractories, for example, depending on the temperatures likely to be reached. Simple conduction of heat through homogeneous materials occurs according to the formula:

$$\Phi = \frac{K \cdot A (\theta_1 - \theta_2)}{x} \qquad (1)$$

where Φ is the steady heat flow in B.t.u./hr., K is the thermal conductivity of the insulator in B.t.u./hr. ft. deg. F., A sq. ft. and x ft. are the area exposed to heat and the thickness of insulation respectively, and θ_1 and θ_2 are the temperatures in deg. F. on either side of the insulation. It is clear that Φ is minimised by employing a material of low K of the greatest reasonable thickness.

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Whereas such steady conduction of heat may often occur through the walls of an oven or refrigerator, the heat transfer under fire conditions is more involved. The outside temperature θ_1 is likely to rise continuously, causing the heat flow rate to increase. Furthermore, much of the heat flowing in will reach the contents of the enclosure and thus raise the inside temperature θ_2, the remainder causing a general temperature rise of the insulation itself. Such unsteady heat conduction is represented by the following relation:

$$\frac{\partial \theta}{\partial t} = \alpha \cdot \frac{\partial^2 \theta}{\partial x^2} \qquad (2)$$

This means that the rate of change of temperature with time at some point in the wall varies as the second differential coefficient of the temperature with respect to the distance into the wall. α is a property of the material known as *thermal diffusivity*, measured in ft.²/hr., and given by:

$$\alpha = \frac{K}{\rho C_p} \qquad (3)$$

where e is the density in lb./cu. ft., and C_p is the specific

TABLE 1. Some mean values of thermal properties

Materials	Conductivity K (B.t.u./hr. ft. °F.)	Heat Capacity ρC_p (B.t.u./ft.³ °F.)	Diffusivity α (ft.²/hr.)
Cork	0·029	2·9	0·010
Wool felt	0·025	4·1	0·006
Wood shavings	0·034	3·1	0·011
Corrugated asbestos	0·031	4·0	0·008
Glass wool	0·035	1·0	0·035
Rock wool	0·024	1·6	0·015

TABLE 2. Thermal properties of some dehydrated insulators

Materials	Conductivity K (B.t.u./hr. ft. °F.)	Heat Capacity ρC_p (B.t.u./ft.³ °F.)	Diffusivity α (ft.²/hr.)
Diatomaceous earth	0·050	3·8	0·013
Vermiculite	0·130	4·2	0·031
Gypsum	0·062	14·0	0·004

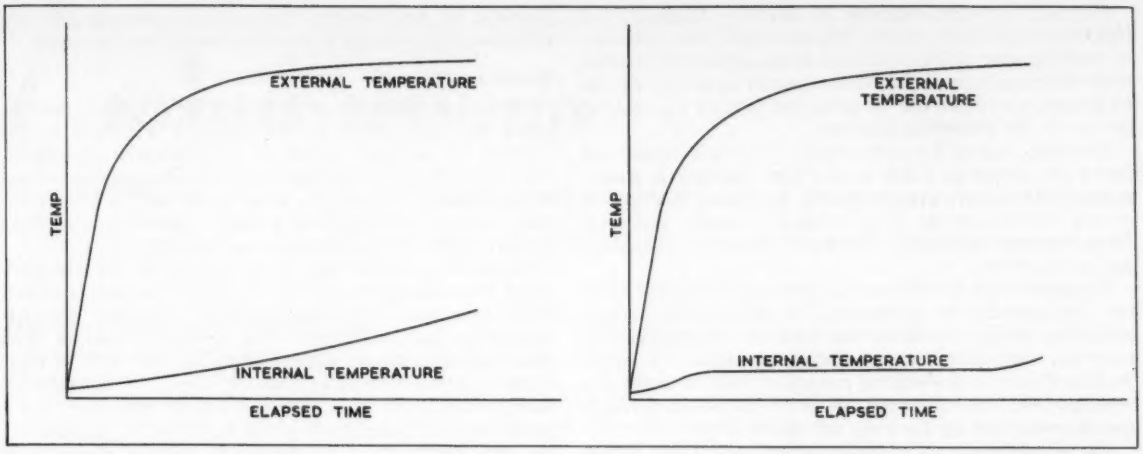


Fig. 1. Temperature-time curves, using homogeneous insulation.

Fig. 2.Temperature-time curves, using hydrated insulation.

heat (at constant pressure) in B.t.u./lb. deg. F. The product $\rho \cdot C_p$ is the *heat capacity* of the insulation in B.t.u./deg. F. per cu. ft., that is, the quantity of heat the insulation can absorb per degree rise of temperature for each unit volume of its bulk. Since K should be low, and heat capacity should be high, a good insulator must have a low value of thermal diffusivity.

It is now clear that if a homogeneous insulator is used, it must itself absorb the great majority of the heat entering the enclosure, so that the contents suffer only a moderate temperature rise. Table 1 gives some relevant properties of a selection of materials used for insulation against heat. It is seen that, although the materials listed all have low K values of the same order of magnitude, there is a wide variation in heat capacity and therefore of diffusivity.

Whereas the manner in which temperature rises with time in a severe fire has been laid down by standard, it is difficult to calculate with any accuracy what occurs on the inside of an insulated box exposed to such a fire. Local convection effects adjacent to either surface are unknown, and the heat capacity of the contents of the box is a variable quantity. Fig. 1 shows the standard temperature-time curve applied as the external temperature of the box. The second curve shows the manner in which the inside temperature might be supposed to rise with time for a material of very low diffusivity. A practical test is the only reliable way of establishing such a curve for a particular combination of circumstances. In general, none of the available homogenous insulators will afford satisfactory protection unless an unduly large thickness of insulation is employed.

Added Moisture

Turning now to the proposition of employing insulators which are capable of absorbing water, a complex material structure is obtained which does not behave according to the laws of heat conduction already discussed.

Consider, for example, a wall made of wet sawdust sheathed in steel sheets. As the temperature rises on the outside, a layer of water will soon reach boiling point, and within the confines of the sheathing will remain at boiling temperature as the layer receives latent heat of vaporisation for conversion into steam. Since this process occurs without appreciable rise of pressure above atmospheric, the temperature inside the evaporated layer will not rise much above 100 deg. C., and the resulting steam, which is likely to be very nearly dry, will escape from the insulation. The material remaining in the layer, in its almost dry state, will continue to act as a normal insulator. Successive layers of insulation will be dried out in the above manner as time elapses, and the temperature inside the wall will rise to about 100 deg. C. and remain at this temperature until all the moisture in the wall has been evaporated. This process is illustrated in Fig. 2. Subsequently, the wall will act as a normal insulator, and the inside temperature will again rise.

Very fortunately, 100 deg. C. is below the danger point for many materials and equipment and thus it may be in order for the inside temperature to remain at 100 deg. C. for a long period.

The heat capacity of the wall is greatly increased by the presence of the water, to the extent of the heat required to boil the water and then to supply the latent heat of vaporisation; in fact, the effect is to multiply the heat capacity several times, depending on the ability of the material to absorb moisture.

Unless great care is taken to seal in the moisture during the manufacture of the enclosure, it will all evaporate at ordinary room temperature early in the life of the product. The remaining dry insulator will offer no more effective protection against fire than the homogeneous materials considered earlier. Furthermore, during this early period, the contents will be damp and local rusting of the steel structure will occur. It is quite clear that, despite the great advantage of added moisture in increasing the fire protection, the use of *free* moisture is of little or no value, because in the unfortunate event of a fire occurring, this may not happen for many years. Some means of manufacture whereby the moisture is included in suitable materials in chemically-bound form is necessary to ensure permanent protection.

Combined Moisture

A number of insulating materials suitable for the temperatures encountered in fires are available for processing, so that water of crystallisation is permanently retained under normal atmospheric conditions. These are mostly hydrated sulphates and silicates. Some of the more common are mentioned below.

Diatomaceous earth is a form of silica formed from the skeletons of minute algæ and occurs in a fine porous form on the earth's crust. It is hydrated to a small extent, and is also capable of absorbing a considerable amount of free moisture. One of its main uses is that of an absorbent, but it is also of value as a heat insulator.

Vermiculite is a complex hydrated aluminium-iron-magnesium silicate, mined in the U.S.A. and Africa. A form of mica, it is formed in flaky layers containing moisture entrapped between the layers. Heat causes some water to be evaporated and changes the flakes into very light cellular granules, suitable for lagging roofs and hot water cylinders, etc.

Gypsum is found naturally in northern England, and consists of hydrated calcium sulphate with two molecules of water. Plaster of Paris is made from gypsum by heating until three-quarters of the water content is driven off. As an insulator, gypsum can be processed into strong castings for use in fire-protective cabinets.

The properties of the above materials in their dehydrated forms are shown in Table 2. The heat capacity is greatly augmented in each case when the combined moisture is present, but the amount of the increase is largely dependent on the manner adopted by the manufacturer in processing the raw materials.

When materials like the above, containing combined moisture, are used for fire protection, the heat-transfer process is similar to that described for materials containing free moisture, with the advantage that the moisture is retained indefinitely unless released by the intense heat of a fire. No rusting of the metal structure can occur, nor do the contents become damp during the early life of the product.

One disadvantage of insulators containing water is that some moisture is released internally during a fire, and although this is not detrimental to paper, such materials as some electrical insulation and film must be protected in air-tight containers if they are not to be damaged.

Finally, it must be remembered that fire protection afforded by the presence of combined moisture will only safeguard the contents of an enclosure on one occasion.

Further Trends

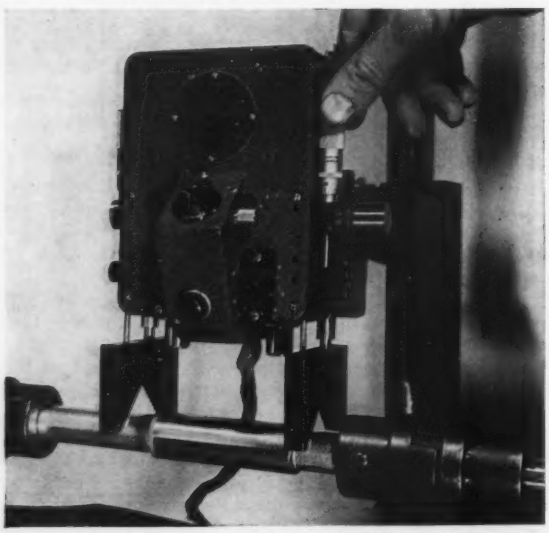
Further development of materials for fire protection depends on the possible establishment of standards in this country for different classes of manufactured equipment. This would foster a demand for certified equipment based on public trials of cabinets which have been in service for many years, as well as of new products. Some manufacturers already carry out such trials on a voluntary basis.

Research is needed into the processing of new materials which have high heat capacity of a permanent nature, which at the same time exhibit good mechanical strength. Materials containing combined moisture are likely to be used for some years for contents of cabinets which are well able to withstand a temperature of at least 100 deg. C. A big advance would be made if the combined fluid was not water, but a non-poisonous compound which boiled at a temperature between 40 deg. and 65 deg. C. at normal atmospheric pressure, which possessed latent heat of vaporisation at least equal to that of water, and had no detrimental effect on film. This is a difficult proposition, but one which must be tackled if a considerable improvement in fire protection is to be realised.

VERSATILE PHOTOSTRESS OPTICAL TRANSDUCER

THE photostress gauge is an instrument which, by means of bi-refringent plastics and polarised light, changes strain levels into contrasting colours which can be analysed in terms of stress, load, pressure, torque and other physical phenomena. Photostress can be used either dynamically or statically to assess the strength of any structure in service. It can be applied on almost any material, such as metals, concrete, wood, rubber and plastics, to solve stress investigations accurately on actual structures and parts.

The heart of the photostress gauge is a small rectangular piece of plastics mirrored on one side, covered with a polarising material on the other, and incorporating a graduated scale. Contrasting colour fringes are always visible along the gauge's length. Applied strain along the axis of the gauge causes the colour fringes to shift to a new position on the scale. When the gauge is bonded to a structure to which a load is applied, the load strains the metal which, in turn, strains the gauge. For every strain level, the fringes on the gauge assume another position, the displacement of the fringes being directly proportional to strain. Since the gauge is calibrated, the strain is indicated by the fringe position and is read directly from the scale. The strain sensitivity will be within 20-40 micro-in./in., depending on the type of gauge. Therefore, it is a self-contained, direct-reading strain-sensitive device requiring no instrumentation.



A photostress torquemeter transducer made by the Tatnall Measuring Systems Co.

When used for transducer applications, the gauge is calibrated in terms of lb. (load), in-lb. (torque), p.s.i. (pressure), etc.

As a strain gauge, the gauge bonded to the specimen is used as an extensometer and will indicate the strain due to the tensile load. It also indicates if the specimen is aligned.

When required as a torque indicator, special photostress gauges are available in which readings are obtained by observing the gauge with stroboscopic light while the shaft is rotating. Torque values are obtained from strain readings or by calibrating the shaft.

For use as a safety device, two gauges have been applied to the columns of a hydraulic press, the gauges indicating the magnitude of strain on each column and measuring any unequal load on the columns. They also indicate any overload. As a pressure gauge, it is bonded to a pressure diaphragm and indicates pressure values in p.s.i.

An ordinary wrench may be converted to a torque-measuring wrench by bonding the photostress gauge to its handle. The wrench is calibrated in in.-lb. torque.

OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Mercury Plasma Tunnel of Glass

In order to permit the study of ionisation effects in continuous flows while avoiding the high temperatures required for thermal ionisation, applicability of glow discharges to supersonic flows has been investigated at the Convair Scientific Research Laboratory. It is well known that in discharges of this type only the electron component of the gas acquires energy comparable to the gas ionisation potential, while the main body remains far below this level.

These considerations have led to the design and construction of a small tunnel, the entire system for which is blown out of Pyrex glass with the exception of the nozzle, which is made of Vycor to withstand higher temperatures. The biconical nozzle has a throat diameter of 4 mm. The exit diameter is 50 mm. and the length of the supersonic portion 130 mm. The nozzle and the other parts are connected by ground joints and are interchangeable. A small vacuum pump keeps the residual air pressure at the micron level. The mercury at the bottom of the boiler is heated to temperatures between 200 and 250 deg. C., corresponding to vapour pressures (and approximately stagnation pressures) between 15 and 75 mm. Hg. A resistance coil embedded in a glass spiral that stretches from top to bottom of the boiler allows superheating of the vapour to about 450 deg. C. To reduce heat losses the walls are also heated electrically and carry heavy asbestos insulation.

High-speed Carburising

Acceleration of the carburising process by increasing the saturation temperature has been developed in Russia in recent years. In mass production, the use of induction heating in gas carburising has been successful In batch manufacture, the use of induction heating in pack carburising was suggested several years ago, but trouble has been experienced with uneven saturation and frequently the over-saturated regions melted.

A thorough investigation of the process is understood recently to have been carried out by Russian engineers to overcome these difficulties and to discover the principal factors in high-temperature pack carburisation.

The carburised components, packed in a carburiser, were placed in a crucible made of graphite and covered on the outside with a fireclay composition. The crucible was wrapped in asbestos sheet and surrounded with an inductor coil supplied with high-frequency current at 200 kc/s from a 30-kW. generator.

The carburiser consisted of a composition containing 16 per cent $BaCO_3$ mixed with charcoal. Mild steel (0·20 per cent C) and chromium-nickel steels (types 12 KhN3A and 18 KhNVA) in 18-mm. diameter 70-mm. long samples were investigated by metallographic analysis and mechanical tests. Plate specimens of 1, 2, and 3 mm thickness, 10 × 70 mm. in plan, were examined, after thorough carburising, to find the properties of the carburised layer.

These investigations yielded a method for the prevention of local over-saturation. This consists of covering the surface of the carburised components with a paste that is permeable to gas but otherwise inert. A chalk powder paste mixed with water has been found effective and easily removable after processing.

Broadly, carburising at a temperature of 1,000 deg. C. reduces the duration of the process by a third compared with the standard process. A five-fold reduction is obtained at 1,150 deg. C.

The carburising temperature also has other effects on properties of the carburised layer. An increase in temperature increases the depth of the layer and reduces its carbon saturation. Another factor is the carbonate salt content in the carburiser. It is stated that the optimum $BaCO_3$ content is about 9 per cent.

A rapid growth of austenitic grain was observed when high temperature was maintained. The growth is most pronounced in the carburised layer and less so in the core. For this reason, a single quenching treatment results in a coarse grain structure and a tendency to preserve residual austenite.

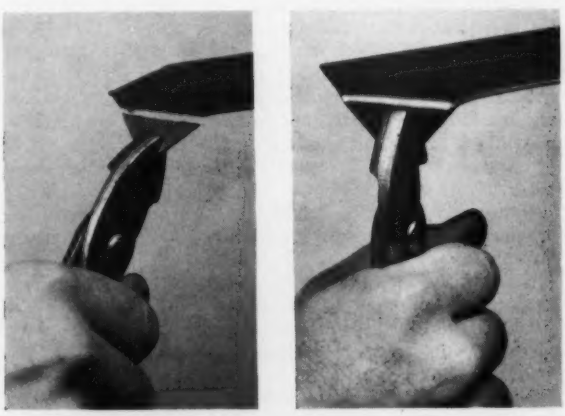
In order to improve the mechanical properties, a grain-refining double heat treatment must be applied.

High-ductility Molybdenum Sheet

A new type of pure molybdenum sheet of far greater ductility than hitherto available which has been developed in the U.S.A. will simplify many of the processes where it is now used.

Where temperatures as high as 540 deg. C. have in the past been needed for the manufacture of many formed molybdenum parts, the new high-ductility sheet can now be bent at right angles or double upon itself at room temperature, thus making it ideal for punching and deep-drawing operations.

Molybdenum is one of the most widely used refractory metals, and its value lies mainly in its high melting point, low vapour pressure and excellent mechanical strength at elevated temperatures. Its other unusual properties make



Normal grades of molybdenum have a low ductility and break easily—as shown in the left-hand picture. On the right is a test with the new G.E.C. high-ductility molybdenum sheet, which can even be bent double.

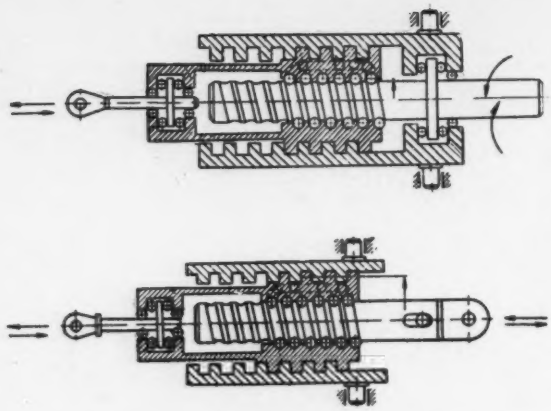


Fig. 1 (above) and Fig. 2 (lower illustration): Two Russian versions of a self-locking screw jack. See story right.

it a key material in many defence and industrial applications, notably the production of electronic tubes, transistor diodes and rectifiers, light sources and high-temperature strength parts.

The new H.D. molybdenum sheet developed by G.E.C. shows as much as five times the room-temperature ductility of ordinary molybdenum sheet under the Erickson cup test method of determining ductility of sheet products, and is made by powder metallurgy techniques in which metal powder is pressed into an ingot, consolidated into massive metal by high-temperature sintering and worked into sheet by rolling.

Improvement in the ductility and bend properties exhibited in this product is of particular significance in thicknesses from 0·025 to 0·125 in.

Based on preliminary data, tensile strengths of between 105,000 and 120,000 p.s.i. are typical, failures of the new sheet tested by the Alexander method are in all cases of the ductile, not brittle, type.

Chains of Glass-reinforced Plastics

The production of chains made from glass fibre-reinforced plastics is the subject of a recent article in the German periodical, *Industrie-Anzieger*. They have been developed by a Westphalian chain manufacturer, who foresees a future for them as a less expensive substitute for corrosion-resistant steel chains.

The separate links consist of specially-constructed plastics mouldings, preferably of polyamide or polythene, but also more recently made of a modified p.v.c., into which are inserted a glass fibre cord with a polyester binder. This glass filling constitutes about 60 per cent of the total weight of each chain link. They have a specific gravity of about 1·8.

If necessary, the plastics of the outer moulding can be provided with a lubricating additive such as molybdenum disulphide.

Because the chain links are not circular and the fibre tension of the glass strand is not uniform along the circuit of the link, the moulding is reinforced within the curved portion to prevent flattening at the head of the link.

The standing load values (tenacity) of the glass-reinforced plastics are some thousands of times higher than plastics not reinforced with glass. They are at present made with a minimum diameter of about 10 mm., though thinner versions are being produced experimentally.

These chains are not likely for some time to compete seriously with steel chains, but they are said to be proving valuable in applications where the low density or other properties of plastics can be used more satisfactorily.

Efficient Self-locking Screw Jack

In ordinary two-component screw jack mechanisms, a high efficiency is not usually found in these devices if they are self-locking. For example, sliding friction screw jacks are self-locking, but normally have a low efficiency. Screw jacks with recirculating balls have a high efficiency but are not self-locking. Theoretically, the efficiency of self-locking screw jacks cannot exceed 50 per cent, and is usually well below this value.

Three-component screw jacks have already been described by German investigators. In a recent Russian report it is shown that three-component screw jacks can be so designed that they combine the property of self-locking with a relatively high efficiency, exceeding 60 per cent.

Fig. 1 shows a three-component screw jack mechanism which transforms a rotary into a translatory motion. The functioning of the mechanisms is self-explanatory. Fig. 2 shows a screw jack for transforming one translatory motion into another.

An analysis of the operation of these mechanisms has yielded expressions for their efficiencies which have been experimentally verified by the Russian investigators. Analysis and experiments have shown close agreement and have proved the existence of self-locking together with a mechanical efficiency of about 63 per cent.

Giant Truck

The world's largest truck—16 ft. wide and 41 ft. in length—has recently been built in France. The Berliet T.100 has a payload of 100 tons, and, fitted with Goodyear 8-ft.-diameter low-pressure rubber tyres, is capable of negotiating soft sandy terrain considered impassable for most vehicles. The total bearing area of the six tyres is 100 sq. ft., which results in a ground pressure of only 14 p.s.i. The Berliet T.100 is fitted with power steering, power brakes and a power-assisted gear change mechanism which operates on eight forward and eight reverse speeds, the engine being a 600-h.p. turbo-diesel. The cab is fitted with air conditioning, a two-way radio, sleeping berths and cooking facilities.

The first of these vehicles has been exported to the U.S.A., where it is to be used for exploiting natural resources in otherwise inaccessible areas.

Wide Extrusions

A special technique has been developed by Harvey Aluminium in the U.S.A. to extrude stiffened panel sections of 28·08 in. width. Using a 12,000-ton hydraulic press, these integrally-stiffened panels are extruded in 7178 alloy on a production basis for final machining into structural wing components.

On the big presses, aluminium structural shapes, comparable to the largest fabricated steel sections, can be extruded with the added advantages of better strength-to-weight ratio, individual design, lower fabricating costs and excellent resistance to corrosion.

Some of the newer uses for these big aluminium extrusions are curtain walls, ship decking, truck-trailer sections, airframe parts, missile bodies, helicopter blades, bridge and highway constructions, pipelines and materials handling equipment.

Engineering Materials and Design

DATA SHEET No. 26

SPRING STEEL STRIP

Stainless Steel—SANDVIK 2R25

Chemical composition, %

C	0·1	Si	1	Mn	1·3
Cr	17	Ni	8	Mo	0·7

Physical properties (annealed condition)

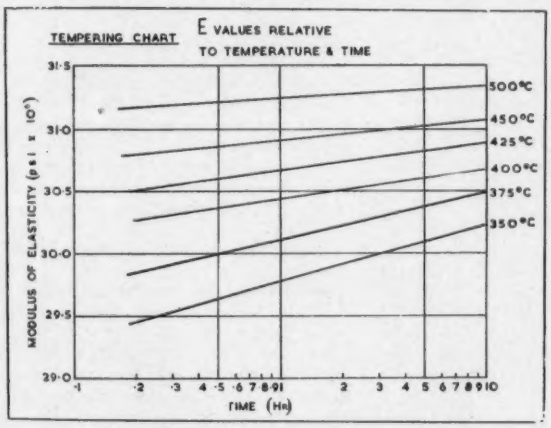
Density	0·285 lb./in.³
Thermal conductivity at 20°C.	0·036 cal./cm. sec. °C.
Specific heat, mean value 50–100°C.	0·12 cal./gm. °C.
Thermal expansion, mean value 20–100°C.	$16{\cdot}8 \times 10^{-6}$/°C.
Electrical resistivity at 20°C.	89 microhms—cm.

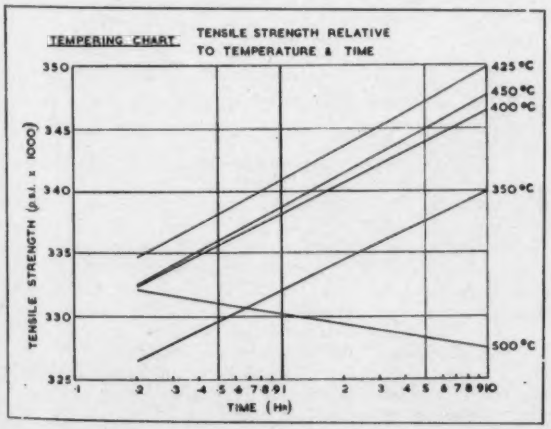
Mechanical properties (approx.)

	Extra Hard Rolled (3 categories)			Extra Hard Rolled and Tempered, 425°C. for 4 hr. (3 categories)		
U.T.S. p.s.i. × 10^3	240	270	300	275	305	340
0·1% proof stress, p.s.i. × 10^3	115	140	170	150	180	215
Elongation % in $11{\cdot}3\sqrt{A}$	2–4	2–4	2–4	2–4	2–4	1–3
Modulus of elasticity, p.s.i. × 10^6						
longitudinal	25·6	26·3	27·7	27·0	27·7	29·2
transverse	–	–	34·1	–	–	35·6
Fatigue strength, p.s.i. × 10^3 load cycles 5 × 10^6 (reciprocal bends)	–	–	–	82·5	75·4	61·2

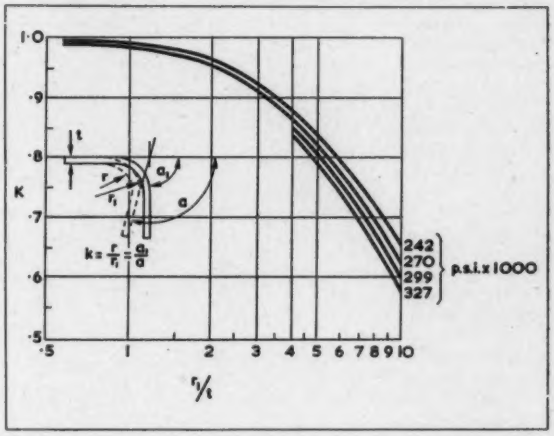
Scaling temperature in air: 875°C.

Effect of elevated temperatures on use: Little change in properties up to about 400°C.





To compensate for spring-back in the material, allowances should be made when designing form tools and bend blocks as indicated in the example below.



Minimum bend radii for bending across the grain

Strip Thickness, in.	Minimum Radii for the Following Tensile Strengths			
	242,000 p.s.i.	270,000 p.s.i.	299,000 p.s.i.	327,000 p.s.i.
0·004	0	t	5t	5t
0·008	t	3t	10t	10t
0·016	t	4t	—	—
0·024	2t	5t	—	—

Example:

A finished component requires a bend angle of 90 deg. and a bend radius of 0·08 in. To allow for spring-back, the form tool bend angle and bend radius are calculated as follows:

$$\frac{r_1}{t} = \frac{0{\cdot}08}{0{\cdot}016} = 5$$

K (from graph) = 0·82

$$\text{now } K = \frac{r}{r_1} = \frac{a_1}{a}$$

$$\therefore r = K \times r_1$$

$$0{\cdot}82 \times 0{\cdot}08$$

$r = 0{\cdot}656$ = bend radius for tool.

bend angle = 180 — a

$$\therefore \text{tool bend angle} = 180 - \frac{a_1}{K}$$

$$= 180 - \frac{90}{0{\cdot}82}$$

$$= 180 - 110$$

Tool bend angle = 70 deg.

Data by courtesy of Sandvik Swedish Steels Ltd.

New Books

Tunnel Engineering. *By Rolt Hammond.* (*Heywood, 55s.*)

This is a really practical text-book which can be recommended to every civil engineer concerned with the subject. The chapter dealing with tunnel linings provides useful comparisons of the various methods and types of lining. The reference to actual contracts will enable practising engineers to solve many tunnel lining problems, while a further chapter describes the type of shields used. This, together with the very clear photographs, makes easy reading even for the junior engineer.

"Subaqueous Tunnelling" is a rather misleading heading for Chapter 4, since it deals in great detail with the use of air locks, and these form such an important aspect of tunnelling that a separate chapter might well have been included. The remainder of the chapter is of practical use, but it is perhaps a pity that so much vital and well-thought-out advice has been a little mixed up.

Reference to the Woodhead New Tunnel is an excellent example of a "conducted tour" in print and enhances Chapter 5 on "Rock Tunnelling", a book-length chapter containing much valuable and practical data.

The chapter dealing with long tunnels could have been usefully developed, especially the subject of ventilation which presents problems that must be overcome before such projects as the Channel Tunnel are completed.

J. C. Maxwell-Cook

Mechanical Design and Analysis. *By R. R. Slaymaker.* (*Chapman & Hall, 76s.*)

For years text-books on machine design and analysis have followed the same dreary pattern, and to find an exception to this rule is almost an exciting experience. In compiling this book, the author has taken the trouble to approach the subject initially from the practical aspect, dealing with the particular theory as it becomes relevant. While this means a limit to the number of specific examples which may be used, they have been carefully chosen to be representative of the many varied problems which can arise. As every student knows only too well, the most difficult part in design analysis is to apply the mathematics to a practical problem, and this book will go a long way to integrate the two.

The examples solved cover statics and dynamic problems, material selection, gears, belts, drives and bearings.

Paint Trade Manual. *By H. W. Chatfield.* (*Scott Greenwood, 30s.*)

This manual, now in its third edition, while intended mainly for the paint trade, is a useful reference book for engineers. It is probably the most comprehensive work of its kind ever produced: for example, more than 700 paint and varnish manufacturers are listed. Solvents and plasticisers are listed with basic properties, together with the suppliers. Also of interest are the lists of manufacturers of plant and laboratory equipment, and of special products such as temperature-indicating paints, water-repellents and vapour phase inhibitors.

Arc Welding in Machinery Design and Manufacture. (*Lincoln Arc Welding Foundation, $2.50.*)

For the engineer associated with the design of welded structures, this is an interesting and useful publication that describes itself as a "reference manual of ideas for the efficient use of steel in machine design". Of particular interest is the "Problem Reference Index", listing common problems and factors of importance, together with case histories showing how these have been overcome.

Handbook of Mathematical Tables and Formulas. *By R. S. Burington* (*McGraw-Hill, 25s.*).

This latest edition contains most of the mathematical data which the busy designer is liable to forget without frequent use, but will certainly need at some stage. For the student it provides all the necessary reminders which can be absorbed at odd moments, the book being of such size as to fit the pocket.

Formulæ and theorems from algebra, geometry, trigonometry, calculus and vector analysis are given, followed by tables of five- and seven-place logarithms, trigonometrical functions, squares, cubes and reciprocals and lesser used but valuable probability functions, annuities. compound interest and mortality tables.

Heat Pump Operation in Great Britain. *By M. V. Griffith.* (*Electrical Research Association, 24s.*)

There is evidence that a renewed interest is being shown in heat engines, and this E.R.A. report makes a timely appearance. Indicating the availability and utilisation of heat sources, possible extensions of the use of the heat pump, and backed by the results of the Shinfield Experiment, the report gives factual and useful data.

Study of Various Methods of Heat Application to Commercial Range Heavy-duty Top Sections.

Engineering in domestic cookers may perhaps be regarded as a limited and specialised subject. Nevertheless, it is of considerable importance and, if only for that reason, two reports recently issued by the American Gas Association Laboratories are of interest to designers in this field. Research Bulletin No. 76 ($2) covers research on new designs for range top burners, pilots and valves, and Research Report No. 1284 is issued in four parts (each $1.50) under the above title.

Kinematics. *By V. M. Faires* (*McGraw-Hill, 66s.*).

Kinematics are all too often included merely as a section in text-books of mechanics, and thus the subject does not receive the full treatment it deserves. This book makes up for the deficiency and gives a comprehensive treatment to the basic theorems on velocities and accelerations. Particularly comprehensive are the chapters on linkages, cams and gears. Specific problems and answers are given, but the real value of the book lies in its usefulness as a practical reference book for designers.

Who's Who in the Motor Industry. *Edited by F. J. Findon* (*Temple Press, 42s.*).

This work, now published in a third edition, is one of those reference books which are so valuable to many sections of the engineering industry. In addition to the biographical section, the manufacturing section deals with complete vehicles, engines and accessories, components and materials, the latter being probably the most useful.

Surface Treatment and Finishing of Aluminium and its Alloys. *By S. Wernick and R. Pinner* (Robert Draper, 90s.).

The second edition of this book has been well conceived and executed, the presentation enabling the relevant matter to be easily digested. The subject-matter is extremely comprehensive and deals in logical order with the nature of aluminium and its alloys, problems of corrosion and protection. The following eighteen chapters are devoted to the many different processes involved in polishing, cleaning, etching, conversion coatings, decorative and protective anodising. Enamelling and metal spraying are included and the detailed information makes this one of the most useful reference books of its time.

New standards published by the B.S.I. include:

B.S. 3082: 1959. Mechanical testing of steel at elevated temperatures. Part 2—Stress rupture (4s.).

B.S. 601 (Revised). Steel sheets for magnetic circuits of power electrical apparatus. Part 1—Non-oriented steel (6s.).

B.S. 2509: 1959. Form and presentation for periodicals of reference value (6s.).

LETTER TO THE EDITOR

Sir,

The description of the flyback mechanism which you gave in "Designer's Notebook" in your October issue did not stress its prime virtue—which is that the reciprocating motion can be precisely synchronised with the rotary motion.

For instance, the cam-selecting mechanism illustrated actually incorporates a rotary selector switch which keeps in perfect step with the linear member.

S. Zillwood Milledge

77 Northway,
London, N.W.11.

ALUMINIUM BUS-BAR

(fulfilling B.S. 2898)

Specification	E1E	E91E
U.T.S. (min.), p.s.i.	8,960	29,100
0·1% proof (min.), p.s.i.	4,480	23,500
Elongation, % $4\sqrt{A}$	25	10
Modulus of elasticity × 10^6	10	9·5
Electrical resistivity (max. at 20°C.) microhm-cm.	2·873	3·133
Electrical conductivity (I.A.C.S.), %	60	55
Temp. coeff. of resistance per °C.	0·00403	0·00364
Coeff. of linear expansion (20–200°C.)	0·000023	0·000023
Thermal conductivity (at 100°C.), c.g.s. units	0·53	0·43

RECTANGULAR BUS-BAR

Electrical characteristics of rectangular bus-bar

Size	Spec. E1E	Spec. E91E
in.	D.C. resistance (max.), microhms/ft. at 20°C.	
1 × ¼	54·30	59·24
1½ × ¼	36·20	39·49
2 × ¼	27·15	29·62
2½ × ¼	21·72	23·70
3 × ¼	18·10	19·75
4 × ¼	13·58	14·81
5 × ¼	10·86	11·85
6 × ¼	9·05	9·87
2 × ⅛	18·10	19·75
3 × ⅛	12·07	13·16
4 × ⅛	9·05	9·87
5 × ⅛	7·24	7·99
6 × ⅛	6·04	6·58
8 × ⅛	4·52	4·94
3 × ½	9·05	9·87
4 × ½	6·79	7·40
5 × ½	5·43	5·92
6 × ½	4·52	4·94
8 × ½	3·39	3·70
10 × ½	2·71	2·96

Engineering Materials and Design

DATA SHEET No. 27

To obtain the correct rating for material to Spec. E1E, multiply the appropriate figures below by 1·03.

For multiple bar arrangements, the space between the bars is equal to the bar thickness.

A.C. ratings are based on spacings at which proximity effects are negligible.

Ratings may be increased by approximately 20 per cent if the bus-bars are painted with a non-metallic matt-finish paint.

Correction factors for temperature rise

Temperature Rise	Derating Factor
Bar temp. rise 40°C. over ambient (35°C.)	0·88
Bar temp. rise 30°C. over ambient (35°C.)	0·75

Correction factors for enclosed bus-bars

Type of Enclosure	Cross-sectional Area ÷ Total Cross-sectional Area of Enclosure	Derating Factor
Outdoors	1%	0·95
	5%	0·90
	10%	0·85
Indoors: enclosure in well-ventilated room	1%	0·85
	5%	0·75
	10%	0·65
Indoors: enclosure poorly ventilated and room temperature high	1%	0·65
	5%	0·60
	10%	0·50

***SOLID ROUND BUS-BAR**—Mechanical and electrical characteristics and current rating (Spec. E91E)*

Dia.	Weight	D.C. Resistance (max.)	Reactance at 1-ft. spacing, at 50 c/s	D.C. Rating	A.C. Rating at 50 c/s
in.	lb./ft.	microhms/ft. at 20°C.	microhms/ft.	amps	amps
⅜	0·129	134·4	84·4	155	155
½	0·230	75·4	79·0	230	230
⅝	0·360	48·3	74·6	335	335
¾	0·518	33·5	71·2	435	435
⅞	0·705	24·7	68·2	550	548
1	0·920	18·9	65·6	690	685
1¼	1·438	12·1	61·4	945	925
1½	2·071	8·4	57·9	1,200	1,160

Current ratings (in amps) of rectangular bus-bar to E1E, for a temperature rise of 50 deg.C. over an ambient of 35 deg.C., as permitted by B.S. 159

Size in.	1 Bar		2 Bars		3 Bars		4 Bars	
	d.c.	50 c/s a.c.	d.c.	50 c/s a.c.	d.c.	50 c/s a.c.	d.c.	50 c/s a.c.
1 × ¼	356	356	718	715	980	970	1,120	1,100
1½ × ¼	520	520	1,030	1,020	1,380	1,350	1,585	1,535
2 × ¼	672	670	1,315	1,290	1,756	1,705	2,050	1,940
2½ × ¼	820	812	1,550	1,510	2,100	2,000	2,430	2,260
3 × ¼	970	958	1,805	1,740	2,440	2,310	2,860	2,620
4 × ¼	1,260	1,235	2,260	2,140	3,060	2,800	3,640	3,200
5 × ¼	1,545	1,505	2,700	2,510	3,660	3,240	4,410	3,700
6 × ¼	1,840	1,780	3,130	2,860	4,290	3,680	5,250	4,240
2 × ⅛	840	830	1,560	1,500	2,090	1,970	2,460	2,260
3 × ⅛	1,210	1,180	2,180	2,050	2,940	2,660	3,510	3,030
4 × ⅛	1,550	1,495	2,710	2,480	3,660	3,150	4,400	3,560
5 × ⅛	1,940	1,860	3,290	2,930	4,450	3,660	5,400	4,200
6 × ⅛	2,260	2,120	3,770	3,340	5,140	4,080	6,300	4,680
8 × ⅛	2,940	2,750	4,800	4,150	6,500	4,900	8,060	5,740
3 × ½	1,405	1,355	2,450	2,240	3,290	2,830	4,000	3,240
4 × ½	1,830	1,740	3,100	2,720	4,170	3,360	5,100	3,900
5 × ½	2,230	2,080	3,720	2,120	5,040	3,900	6,170	4,550
6 × ½	2,620	2,420	4,300	3,500	5,850	4,400	7,200	5,100
10 × ½	4,080	3,640	6,500	5,000	8,860	6,000	10,900	6,850

* These sizes are typical, but others are generally available.

The current-carrying capacity of a number of bars arranged in parallel is considerably reduced because of the mutual screening effect which prevents free dissipation of heat from the surfaces of the conductors.

The ratings apply to bare, unpainted conductors, indoors in still air, and in an unconfined space. For other conditions, the ratings may be obtained by applying the relevant correction factors (see tables above).

contd. on page 637

EMD 1801 for further information

Expansion, contraction and lateral movement of pipe work under extreme conditions of temperature and pressure is no problem to the engineer who has been wise enough to contact and consult TEDDINGTON technicians. Teddington Bellows Expansion Joint cylinders are butt-welded from highly finished cold rolled stainless steel sheet. Convolutions are introduced to give the bellows their characteristic flexibility. Nuclear, chemical, marine and gas engineers acknowledge their efficiency and superiority over many older forms of expansion joint. Wherever pipe-work is subjected to vibration or movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

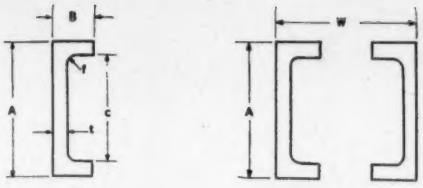
SEND FOR BROCHURE No. X127

Teddington Bellows are produced in technical collaboration with the Solar Aircraft Co., U.S.A.

TEDDINGTON BELLOWS

EXPANSION JOINTS

TEDDINGTON AIRCRAFT CONTROLS LTD. (*Industrial Bellows Division*)
Ammanford, Carmarthenshire. Tel.: Ammanford 2255



***CHANNEL BUS-BAR**—Mechanical and electrical characteristics and current rating (Spec. E91E)*

	One Channel						Two Channels			
A	t	B	c	f			W			
Size in.	Web and Flange Thickness in.	Flange Width in.	Inner Flat Surface in.	Fillet Radius in.	Weight lb./ft.	Resistance microhms/ft. at 20°C.	Width in.	Dc Reactance at 1 ft. spacing. microhms/ft. at 50 c/s	D.C. Current Rating amps	A.C. Current Rating at 50 c/s amps
3	0·217	1·410	1·94	1/4	1·42	12·24	3 1/16	33·2	3,100	3,090
3	0·261	1·498	1·85	1/4	1·72	10·08	3 1/16	35·0	3,380	3,340
3	0·308	1·596	1·76	1/4	2·06	8·42	3 1/16	36·3	3,830	3,760
4	0·225	1·580	2·80	1/4	1·84	9·44	4 1/16	32·3	3,970	3,920
4	0·263	1·647	2·72	1/4	2·16	8·05	4 1/16	32·6	4,250	4,190
4	0·303	1·720	2·64	1/4	2·50	6·95	4 1/16	32·8	4,750	4,650
5	0·238	1·750	3·77	1/4	2·31	7·51	5	28·1	4,820	4,760
5	0·317	1·885	3·62	1/4	3·10	5·61	5	28·2	5,540	5,440
5	0·402	2·032	3·45	1/4	3·96	4·38	5	28·4	6,150	5,880
6	0·264	1·945	4·60	1/4	2·99	5·81	6	24·4	5,900	5,780
6	0·319	2·034	4·49	1/4	3·62	4·79	6	24·5	6,500	6,340
6	0·392	2·157	4·34	1/4	4·48	3·88	6	24·6	7,160	6,850
7	0·328	2·194	5·47	1/4	4·22	4·11	7	21·2	7,550	7,320
7	0·393	2·299	5·34	1/4	5·08	3·42	7	21·5	8,200	7,800
7	0·458	2·404	5·21	1/4	5·94	2·92	7	21·7	8,850	8,330
8	0·327	2·343	6·35	1/4	4·74	3·67	8	18·8	8,500	8,120
8	0·386	2·435	6·23	1/4	5·60	3·10	8	19·0	9,100	8,650
8	0·466	2·560	6·07	1/4	6·78	2·56	8	19·2	9,850	9,150
10	0·445	3·500	7·99	1/4	8·56	2·03	10	14·6	12,000	11,050
10	0·482	3·563	7·91	1/4	9·30	1·87	10	14·7	12,400	11,200
10	0·519	3·625	7·84	1/4	10·02	1·73	10	14·8	12,800	11,450
12	0·418	3·047	10·04	1/4	8·62	2·01	9	10·8	12,200	11,250
12	0·501	3·170	9·87	1/4	10·24	1·68	9	10·85	13,250	11,850
12	0·583	3·292	9·71	1/4	12·06	1·44	9	10·9	14,000	12,050

NOTE: 1. Ratings are for 50°C. rise over 35°C. ambient temperature in still but unconfined air, and equal current in each channel or pair.
2. A.C. ratings are based on spacings at which proximity effect is negligible.
3. Ratings may be increased by approximately 20% if the busbars are painted with a non-metallic matt finish paint.

***TUBULAR BUS-BAR**—Mechanical and electrical characteristics and current rating (Spec. E91E)*

Nominal Size in.	Diameter, in.		Weight lb./ft.	D.C. resistance (max.) microhms/ft. at 20°C.	Reactance at 1-ft. spacing, microhms/ft. at 50 c/s	Current Rating, amp. 50 c/s, a.c.	
	Outside	Inside				Indoors	Outdoors
Standard iron pipe							
1/4	0·840	0·622	0·294	59·22	65·8	384	505
1/2	1·050	0·824	0·390	44·44	61·4	485	625
1	1·315	1·049	0·580	29·89	56·9	675	815
1 1/4	1·660	1·380	0·785	22·15	52·2	845	1,010
1 1/2	1·900	1·610	0·939	18·51	49·6	960	1,160
2	2·375	2·067	1·262	13·76	45·2	1,245	1,440
2 1/2	2·875	2·469	2·002	8·67	41·5	1,720	1,950
3	3·500	3·068	2·617	6·63	37·7	2,130	2,350
3 1/2	4·000	3·548	3·147	5.30	35·1	2,510	2,750
4	3·500	4·026	3·729	4·67	32·8	2,800	3,050
4 1/2	5·000	4·506	4·333	4·01	30·5	3,160	3,420
5	5·563	5·047	5·051	3·45	28·6	3,550	3,810
Extra-heavy iron pipe							
1/4	0·840	0·546	0·376	46·23	66·4	440	575
1/2	1·050	0·742	0·509	34·17	61·8	565	710
1	1·315	0·957	0·750	23·15	57·4	745	925
1 1/4	1·660	1·278	1·035	16·78	52·6	975	1,170
1 1/2	1·900	1·500	1·254	13·85	50·0	1,125	1,335
2	2·375	1·939	1·735	10·02	45·5	1,465	1,680
2 1/2	2·875	2·323	2·647	6·56	41·8	1,955	2,230
3	3·500	2·900	3·543	4·91	38·0	2,470	2,700
3 1/2	4·000	3·364	4·321	4·02	35·4	2,850	3,160
4	4·500	3·826	5·178	3·36	33·0	3,260	3,590
4 1/2	5·000	4·290	6·086	2·86	30·7	3,700	4,040
5	5·563	4·813	7·180	2·43	28·8	4,190	4,550

NOTE: 1. Indoor ratings are for 50°C. rise over 35°C. ambient temperature in still but unconfined air. 2. Outdoor ratings are for 50°C. rise over 35°C. ambient temperature with a crosswind of 2 ft./sec. 3. A.C. ratings are based on spacings at which proximity effect is negligible.

Data from "Aluminium Bus-bar" (Thomas and Rata) by courtesy Northern Aluminum Co. Ltd.

EMD 1802 for further information

NICKEL ALLOY STEELS

ensure reliability in lathes and gear shapers

Automatic factory production methods place a premium on reliability.

To ensure their products do not suffer through material failures, Messrs. Drummond Bros. Ltd., Guildford, specify nickel alloy steels in their "Maxicut" industrial lathes and gear shapers and high production multi-tool machines.

Among the various nickel alloy steels used in Drummond tools is the 4¼ per cent nickel-chromium case-hardening steel, EN 39, which is used for worms and has adequate toughness and wear resistance for this exacting service.

TYPICAL CORE MECHANICAL PROPERTIES OF

EN39

SIZE	HEAT TREATMENT	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
1½" dia.	Oil quenched 830°C. tempered 160°C.	88·2	13	38
2" dia.	Oil quenched 830°C. Oil quenched 760°C. tempered 180°C.	82·1	17·5	61
4" dia.	Oil quenched 830°C. Oil quenched 760°C. tempered 180°C.	77·7	16·5	62

The benefits to be gained from the more highly alloyed case-hardening nickel steels, such as EN 33, EN 34, EN 36 and EN 39 include ease of heat-treatment, minimisation of processing distortion, and general reliability.

Send for "The Mechanical Properties of Nickel Alloy Steels" ▶

TGA 21/2M

MOND NICKEL

THE MOND NICKEL COMPANY LIMITED · THAMES HOUSE · MILLBANK · LONDON SW1

WHAT'S NEW IN MATERIALS & COMPONENTS

Expanded P.V.C.

Plasticell is a rigid, expanded plastics material based on p.v.c., and so processed as to produce multiple, closed polyhedral cells which are all separate, gas-tight and waterproof, and filled with an inert gas.

Several grades of the material are available, all with a high strength-to-weight ratio. It is said to have good resistance to chemical attack and to have excellent electrical and thermal properties (K factor of approx. 0·2 B.t.u./in./h./sq. ft./deg. F.). Microcell Ltd.

EMD 1861 for further information

Heating Film

Developed by the Sierracin Corp. of California, a transparent, conductive coating known as Sierracote is now available in the U.K. The coating is applied by evaporation in a high vacuum, and is applicable to glass or all plastics materials used for such applications as aircraft windscreens. The base material can be formed to shape either before or after the coating is applied. It is said to be unique among transparent heating films in that it can be produced with any surface resistance between 6 and 90 ohms/square. This permits irregularly-shaped areas to be heated uniformly and provides a wide choice of operating voltages. It is said to be completely free from localised "hot spots". D. Napier & Son Ltd.

EMD 1862 for further information

Vinyl Coatings

Coatings based on Du Pont Viton are being manufactured in the U.K. under the name of Adcora V. They give builds of approximately 0·001 in. per application and it is recommended that they be applied by spray over Adcora VT tie coat. They are at present available in black only. While they will cure eventually at ambient temperature, they are brought to temperature for most site applications by firing the equipment. Viton, which forms the basis of this coating, is said to possess an elasticity after extensive periods at 500 deg. F. and to withstand high concentrations of acids, alkalis and halogenous materials. E. & F. Richardson Ltd.

EMD 1863 for further information

Non-woven Fabrics

A range of non-woven fabrics is now available, known as Tyga-Web. The makers claim that a number of important physical properties can be offered singly or in combinations tailored for specific needs. These include absorbency that is comparable to napped flannels, a high retention of absorbed liquids, heat sealability, high wet strength, permeability to air, liquids and solids, and excellent filtering characteristics. The fibre can be selected to provide chemical resistance, high dielectric strength or other needs. Fothergill & Harvey Ltd.

EMD 1864 for further information

Silicone Resin

An experimental silicone resin has been introduced for use in flexible electrical insulation. Known as DP.139, it is designed to impregnate glass cloth at the significantly lower temperature range of 100-120 deg. C. with much improved coating speeds. Glass cloth is very easily wetted by this new product, and a tack-free film is formed after heating for five minutes at 100 deg. C. Treated glass tape is said to retain excellent flexibility and high electric strength at high temperatures. Glass tape coated with DP.139 is claimed to be an efficient insulating agent in class H and class C motors, and in many other applications. I.C.I. Ltd.

EMD 1865 for further information

Angle Sections

A recent introduction to the range of slotted angles is a series of redesigned large-scale sections. Two slotted angle sections at present produced—3½ × 1½ in. and 2¼ × 1½ in.—have been designed to be completely interchangeable, thus allowing greater manœvrability. The object has been to provide large sections which had vastly increased strength, but with the versatility of the smaller angle. New sections are said to be 25 per cent stronger, achieved by removing only a minimum of steel when slotting. Handy Angle Ltd.

EMD 1866 for further information

Creep-resisting Steel

A new austenitic creep-resisting steel, called Esshete 1250, has just been developed for high-temperature service up to 675 deg. C. It is basically a 16/10/6 chromium-nickel-manganese steel with small additions of molybdenum, vanadium and niobium. Its object is to provide a high level of rupture strength combined with good ductility, as well as easy fabrication and weldability. The makers say that it should enable more sophisticated designs at current temperature levels to be adopted by the use of thinner section. Results so far are said to indicate its suitability for superheater tubing, steam pipe and header applications. Samuel Fox & Co. Ltd.

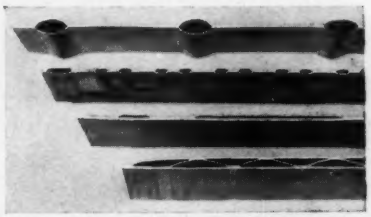
EMD 1867 for further information

Friction Reducer

A method of treating bearing surfaces for wear resistance by chemical means has been introduced with the name of Wynn's Friction Proofing. The product is a compound which is carried in a light petroleum oil so that it can be added to petroleum fuels or lubricants in order to penetrate to the seats of friction. The makers say that it is not an "oil additive" and has no effect on fuels or lubricants; the compound reacts chemically with the bearing metals, and modifies the asperities of their surfaces so that they are less liable to deformation or welding. Three features which the makers emphasise are that no harm is done to the metal surfaces, that friction is radically reduced, and that protection is given against corrosion and condensation. Metal Protection Products Ltd.

EMD 1868 for further information

Combined Sheet and Tube



Noralduct is solid aluminium sheet having internal systems of passages and ducts. It is said to be particularly suitable for heat-transfer equipment and, as the integral passages can follow almost any complex continuous pattern that can be drawn on paper, there are many other possibilities. Sheets of the material can be formed after manufacture, such as those used in refrigerator evaporator components. Either a plain or an impressed pattern finish is available, and the colour can be included in the product design, as there are no welds to spoil the appearance of the anodised finish. Northern Aluminium Co. Ltd.

EMD 1869 for further information

Improved Gunmetal

A new type of gunmetal is now on the market. It is an 85/6·5/3/3·5/2 (Cu-Sn-Zn-Pb-Ni) alloy and is said to have stable and much better mechanical properties at both atmospheric and elevated temperatures than 85/5/5/5 gunmetal, and it still retains the same adaptability to the production of pressure-tight castings. When properly made, castings in this alloy are said to have a 0·1 per cent proof stress of about 8 t.s.i. with a maximum stress of 16-17 t.s.i. in sections up to 3 in. high.

Its use should enable castings to be more effectively designed as regards the use of thinner sections, which could result in weight savings. Mond Nickel Co. Ltd.

EMD 1870 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

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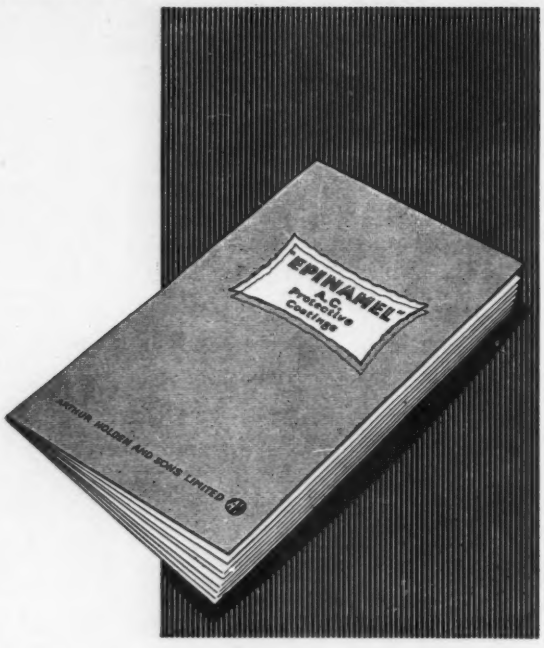
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

EMD 1803 for further information



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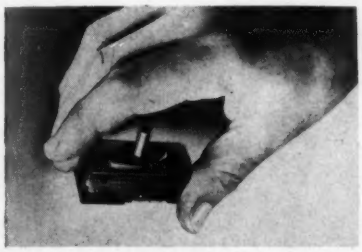
EMD 1804 for further information

Compact Control Unit

Now in production is a compact new control unit specially designed to fit



into the modern thin-wall type of domestic refrigerator. Called the Thinline KCA, it is only $\frac{7}{8}$ in. thick and is claimed to occupy less insulation space than any other model available. Its total weight, complete with feeler and 18-in. capillary tubing, is 2¼ oz. The instrument embodies the capillary and bellows system with a sealed snap switch capable of directly switching up to ½-h.p. a.c. motors or, when used with an absorption-type refrigerator, 500 watts at 220 volts a.c. Teddington Refrigeration Controls Ltd.

EMD 1871 for further information

Valve Mountings

The range and adaptability of British Bellows' Electroaire valves have been further extended by the addition of panel mounting brackets for the ¼, ⅜ and ½-in. port size valves. These give alternative pipe outlets either at the ends of the brackets or from underneath. Two plugs are supplied for blanking off the unwanted ports. Tests on this electrically-triggered but pneumatically-operated valve are said to have revealed speeds of over 1,000 reversals per minute for the ¼-in. port valve. Geo. H. Hughes Ltd.

EMD 1872 for further information

Fastener

The Universal fastener is a recent design of special-purpose fastener with high tensile and shear characteristics. The stud has a fast four-lead thread requiring 270 deg. of rotation to lock and is captivated in the panel with either a steel or light alloy grommet. Studs are available in either flush, oval, wing, ring or knob head formation, in sizes of $\frac{3}{16}$, ¼ and $\frac{5}{16}$ in. dia. Two types of receptacle are provided, rigid or floating, and the rated tensile loads are 1,500 lb. Stub lengths are in increments of 0·1 in., thus enabling various thicknesses of material to be accommodated. Dzus Fasteners (Europe) Ltd.

EMD 1873 for further information

Speedy Fastener

A type of fastener which has been used in aircraft and vehicle production in the U.S.A. is now being introduced in the U.K. Known as the Huckbolt, it is a two-piece fastener consisting of a pin and locking collar. The pin is put through the sheets to be joined as with a bolt or normal rivet. The collar, which has a smooth concentric bore just larger than the pin diameter, slides over the protruding end of the pin up against the sheets. The collar is swaged into locking grooves and the pin is broken at a specific point. The whole operation is effected by a hand-operated pneumatic tool, at a speed of up to thirty a minute by unskilled labour. Aviation Developments Ltd.

EMD 1874 for further information

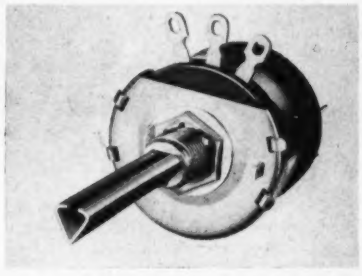
Centrifugal Pumps

An addition has been announced to the range of Monobloc centrifugal pumps. The new series is called type DO and comprises open-impeller pumps specially designed to handle slurries, paper stock, liquids containing small solids, and viscous and clear liquids. Capacities of from 10-360 gal./min. and heads up to 86 ft., depending on capacity, are said to be covered by this range of pumps. Worthington-Simpson Ltd.

EMD 1875 for further information

Hollow Spindle Potentiometer

A new design approach to spindle-controlled variable components is said to be embodied in the production of a triangular spindle potentiometer in which the spindle is formed from flat brass strip. By this design, the need for machining special flats and knob fixings, etc., has been obviated, all locations and



fixings being achieved by bending or forming the hollow brass spindle to accommodate a polystyrene ring which, in turn, holds the brush gear. The limit stop and switch operating lug are also incorporated in the polystyrene ring. Plessey Co.

EMD 1876 for further information

Vibrating Drive Motor

A new electric motor specially designed for vibrating drives, said to be the first of its type made in the U.K., is now being produced jointly and marketed by two British companies. The self-contained unit provides an inexpensive and reliable drive by eliminating all the mechanical parts associated with an eccentric shaft arrangement. Vibration is generated by out-of-balance weights at either end of the motor which can easily be adjusted by single bolts to give the required output.

It is of robust construction, having heavy-duty bearings with special features to deal with out-of-balance loads. Tests are said to have shown that a bearing life of many thousand hours can be expected. Bearings are lubricated for life. The motor is totally-enclosed, dust-proof and weatherproof. Because of its vibrating motion, the motor must be mounted on a resilient base. Operating at 1,500 r.p.m. synchronous speed, it has a power output of up to 7,500 lb. centrifugal force, or 10,000 lb. at 3,000 r.p.m. English Electric Co. Ltd. and Grantham Electrical Engineering Co. Ltd.

EMD 1877 for further information

Midget Air Cylinder

To meet demand for a small, powerful and compact air cylinder, one manufacturer has now added a new midget type to its range. This is a double-acting type with a 1-in. bore. It has a 1-in. neck mounting thread, with a locknut for easy assembly in any position.

The cylinder is ideally suited to the operation of jigs and fixtures, transfer and special-purpose machines. The cylinder body is of brass and has solid-brass endplates of screw-on type. Tie-rods have been eliminated. The cylinder is made in six standard lengths of stroke, i.e., 1, 2, 3, 6, 9 and 12 in. Pressure range is 0-125 p.s.i. air. A. Schrader's Son.

EMD 1878 for further information

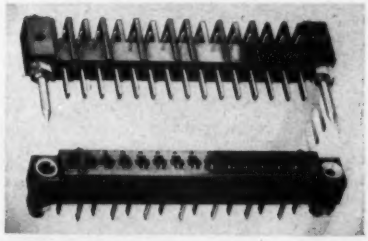
Strain Relief Bushings

Nylon strain relief bushings are now being marketed in this country under the name of IM bushings. These insulate a chassis from a wire or cable and also provide a secure anchorage to an appliance or apparatus. They are said to be simple to snap into a chassis hole in a single operation. Injection Moulders Ltd.

EMD 1879 for further information

Printed Circuit Connectors

A 15-way printed circuit connector is now on the market. It is a heavy-duty design fitted with stainless-steel guide dowels, and is said to be particularly suitable for printed circuits on plug-in chassis. The contacts are on 0·1-in. centres and the plug has right-angle

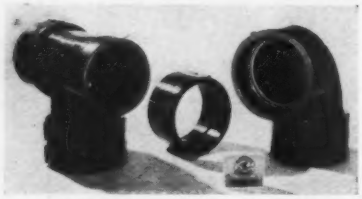


solder tags which project through the standard 0·052-in. holes in the printed board. The design includes provision for a 30-way socket and the stacking of two 15-way plugs to form a 30-way unit, although only the 15-way version is at present available. Painton & Co. Ltd.

EMD 1880 for further information

P.V.C. Pipe Fittings

A new range of 6-in. i.d. fittings, injection moulded in Geon high-impact rigid p.v.c., has been introduced. Claimed



to be the largest mouldings of their kind, they include T-pieces, elbow bends, sockets and flanges, specifically designed for handling crude oil, effluent and allied materials.

These fittings, which are extremely light in weight, corrosion resistant and shatterproof, enable complicated p.v.c. pipeline systems to be constructed in the minimum of time. Durapipe & Fittings Ltd.

EMD 1881 for further information

Pressure Indicator

The MPS.200 range of two-stage pressure switches is suitable for use in either pneumatic or hydraulic systems where high-accuracy pressure indication at two levels is required.

The switch can be set at any two levels in the range 50-6,000 p.s.i. with a very low differential at these two settings, i.e., for a switch set at any two pressures in the range 50-250 p.s.i. the tolerance on a falling pressure is +0 −3 p.s.i. The standard unit is manufactured in mild steel, cadmium plated, but for special application the pressure unit is provided in stainless-steel. This switch is fully approved by the Ministry of Supply for use in aircraft systems and meets all the relevant specifications. The switch can also be used as a single-stage pressure indicator with zero differential between rising and falling pressures. M.B. Metals Ltd.

EMD 1882 for further information

Fluid Seal

A new patent double-acting fluid seal is claimed to eliminate many of the difficulties encountered in the design and operation of double-acting hydraulic pistons. It is based on the Hallprene fluid seal, and is fundamentally two impregnated fabric U-seals bonded to a rubber core.

Conventional practice in sealing double-action mechanisms is to use two seals back to back: one seal operating on the inward and the other on the outward stroke. The difficulty arises of dealing with fluid accumulations between these seals; however efficient they may be in resisting leakage under pressure, there is generally some fluid "creep" between the piston and the seal.

The pocket of fluid thus formed between two seals can cause rapid wear of the seals if it is allowed to remain. It moves from one seal to the other as the piston reciprocates, so that both seals are subject to excessive wear, whether by continuous flexing because the seal is unseated, or by damage to the sealing lips. Usually this wear is minimised by use of vents to allow fluid to escape from behind the seals.

The new seal can be mounted centrally in a groove on the piston spigot, filling the diametrical clearance between spigot and cylinder.

Use of the seal is said to facilitate more economical design of double-acting pistons and allows for longer operation before servicing. They are available in a wide range of standard sizes. Hall & Hall Ltd.

EMD 1883 for further information

. . . at the International Plastics Fair, Dusseldorf

Oederlin & Cie. Gravity cast epoxy resin products for a wide range of electrical and mechanical applications. Kufalit in various grades, graphite-filled for bearings and anti-friction uses, high-temperature grade FWT to withstand 170 deg. C.

EMD 1884 for further information

Hans Kreis Jr. Gears, bushes, nuts, bolts and washers in a wide range of materials such as nylon, polythene and reinforced plastics. Special design of split bolt which tightens on a tapered rod for fixing into tapped holes.

EMD 1885 for further information

Farbwerke Schroeder & Stadelmann A.G. Sustamid (nylon) in form of rod, tube, plate, strip and profiles for the manufacture of bushes, gears, wheels, impellers, screws, nuts, gaskets and insulators.

EMD 1886 for further information

Robert Bosch G.m.b.H. Very wide range of cams, gears, worms, wheels and insulators made from thermoset laminates or nylon.

EMD 1887 for further information

Friedrich Berges. Intricate mouldings of high precision and corrosion resistance, moulded gears from fabric laminate.

EMD 1888 for further information

Norddeutsche Seekabelwerke A.G. Insulating foils for capacitors and cable insulation; also threads from thermoplastic materials.

EMD 1889 for further information

Bezet-Werk Hermann Buchholz G.m.b.H. Small precision mouldings, small injection moulding machines and parts moulded from rigid polystyrene foam.

EMD 1890 for further information

Dr. Deisting & Co. G.m.b.H. Moulded parts for electrical and mechanical engineering, vehicle construction and medical equipment.

EMD 1891 for further information

Dynarohr-Werk G.m.b.H. Pipes for main water supply from 65-150 mm. and pressures up to 10 atmospheres.

EMD 1892 for further information

Eckert & Ziegler G.m.b.H. Fully automatic screw injection moulding machines with injection volumes from 150-2,500 c.c. Injection units are exchangeable and provided with screws of various diameters.

EMD 1893 for further information

Elstein-Werk H. Steinmetz & Sohn K-G. Infra-red radiators and building elements for assembly of complete infra-red units on the building block principle.

EMD 1894 for further information

W. H. Joens & Co. G.m.b.H. Norfa temperature-control device for regulating heating and cooling systems automatically and recording actual temperatures.

EMD 1895 for further information

Georg Fischer A.G. Moulded fittings and valves from hard p.v.c. and polythene, hard p.v.c. parts bonded to metal.

EMD 1896 for further information

Holzverzuckerungs-A.G. Propellers and wheel rims injection moulded from nylon.

EMD 1897 for further information

Carl Huth & Söhne. P.T.F.E. pipes 63-150 mm. diameter; also p.t.f.e. sheets, rods, foils, adhesives and pastes.

EMD 1898 for further information

Aust & Schüttler & Co. Fibre resin spraying equipment for the manufacture of car bodies, tanks, etc.

EMD 1899 for further information

Süd-Stoff, Süddeutsches Kunststoffwerk G.m.b.H. Moulded parts from glass fibre and resin in any variety of shape and length. Speciality pipes and p.v.c.-coated glass fibre fabrications.

EMD 1900 for further information

Stahlkontor Weser G.m.b.H. Simplabelt, an infinitely variable speed transmission system.

EMD 1901 for further information

H. Wernert & Co. K-G. Centrifugal pumps made for handling acids and alkalis, designed without stuffing box and available for horizontal or vertical installations.

EMD 1902 for further information

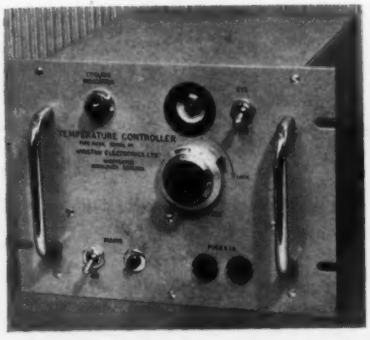
Two useful publications that were on sale at the exhibition were a special edition of *A.B.C. der Deutschen Wirtschaft*, listing 3,500 names in the plastics producing and processing industry, and a *Trade Directory of German Plastics*, published by Krausskopf-Verlag.

EMD 1903 for further information

(See page 605 for a report of general technical trends at the exhibition).

Temperature Control

Extreme reliability and an accuracy greater than 0·025 per cent at 1,000 deg. C. are claimed for the Winston-United Steels controller type M.226. Originally developed for the critical temperature control of furnaces used in creep-testing alloy steels, the present commercial model is suitable for iron and steel foundries, non-ferrous metallurgical research, development and production and



in fact for situations wherever electrical thermometers are used. Using supplies of 200/250 or 100/130 volts at 40/100 c/s, any desired range up to the limits of a platinum thermometer, i.e., 1,200 deg. C., can be controlled. A direct calibrated range of 1,000 deg. C. in ¼ deg. C. is provided. Winston Electronics Ltd.

EMD 1904 for further information

Moisture Detector

With the Shaw moisture alarm it is claimed that where moisture is a critical factor constant supervision is no longer required, as the wet and dry limits of any material are set on the dial of the instrument which will then light a lamp, ring a bell or alter controls beyond the required limits. The alarm indicates the amount of moisture by means of the dial reading; the two adjustable pointers, coloured red and green, are set by two external screws. An external electrode is used and this makes a moisture check by means of a dielectric measurement at a frequency of 100 mc/s. Shaw Moisture Meters.

EMD 1905 for further information

Lower Furniture

A new range of drawing-office furniture, comprising chairs, reference tables, and bench-mounting adjustable drawing stand, has been introduced. This equipment is based on the findings of a research team set up by the B.S.I. which has come to the conclusion that a lower sitting position of 28 in. enables a better posture to be maintained with less fatigue. With the new equipment, it is said that all statures of draughtsmen can have both feet firmly on the ground. Hall Harding Ltd.

EMD 1906 for further information

Test Vibrator

A test vibrator, specially suitable for high "g" valve and component testing, extended fatigue testing and accelerometer calibration, is announced. The EMV 100A has been developed to meet the requirements for a vibrator with a frequency range with full thrust extending to 20,000 c/s. Its usable frequency range covers 1-20,000 c/s and continuous rating thrust is maintained throughout the range of 30-20,000 c/s. The instrument offers a 100 "g" peak, and when used with "white noise" and a peak to r.m.s. ratio of 3:1 the corresponding "g" figures are 212·1 "g" peak and 70·7 r.m.s. The vibrator is completely self-contained and is stressed to give over 100 per cent safety factor for these conditions. E.M.I. Electronics Ltd.

EMD 1907 for further information

Oil-free Compressor

A portable air compressor now available is claimed to give an even 60 p.s.i. flow completely free of oil. This compressor, which is of German manufacture, is designed for use in paint spraying, but can also be employed for other purposes. The twin opposing diaphragm arrangement induces free air, compresses it, and delivers it at 1,400 compressions per minute. Owing to compression, the air temperature approaches 100 deg. C. and a special diaphragm material has been adopted that will withstand continuous operation at this heat. An advanced cooling arrangement using incoming air flow is used.

The design is simple, there being no oil separators or air receiver, and the air filter is changed in a matter of seconds. The compressor delivers 3·5 cu. ft./min. and weighs 77 lb. complete. Plannair Ltd.

EMD 1908 for further information

Desk Calculator

A new and ingenious non-mechanical desk calculator, the Bergmann Unical, has been introduced into this country. This calculator is unique in that it consists of a number of printed cards arranged to be simply turned, and from these answers to multiplication and division problems are directly read. Although unable to perform all the functions of a mechanical calculator, it can, however, provide accurate answers to problems involving four digits on one side and an unlimited number on the other, thereby surpassing the accuracy obtainable by the conventional slide rule. Other interesting functions are the direct working of a problem of mixed fractional to decimal quantities, and the incorporation of factors which enable a reduction of values in terms of months and weeks from yearly totals. Percentage and interest are also directly obtainable. It is claimed that straightforward addition and division can be performed faster and more accurately than with either slide rule or calculator. Kenneth Miles.

EMD 1909 for further information

Co-ordinate Drawing Machines

The Aristo Co-ordinatograph, manufactured by Dennert & Pape of Hamburg, is a high-precision draughting machine on which drawings can be prepared on drawing paper, opaque or transparent foil as well as on coated foil, glass and metal. Originally developed as a cartographic machine, it is now offered with a rotary table specifically designed for engineering drawing.

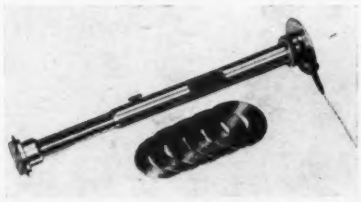
The drawing surface consists of a strictly level glass plate with a translucent cover mounted in a distortion-free metal frame. Both carriages have adjust-

able index windows for direct rough adjustment and release geared recording mechanisms with clamp and slow-motion control. The distance traversed by the carriages is magnified tenfold on the recording dials, and an accuracy of ±0·0012 in. is claimed. Reading of the 360-deg. circle is by vernier.

The Co-ordinatograph would appear to be particularly useful for work in conjunction with optical comparators, the exact layout of precision mechanisms, for copying parts with irregular contours and for preparing graphs and nomograms to fine limits of precision. A number of accessories are available. Technical Sales.

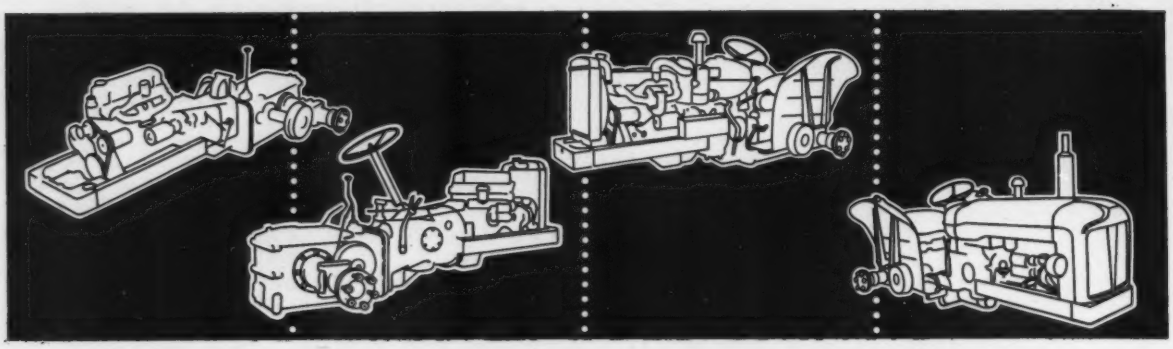
EMD 1910 for further information

Large Arc Instrument



The Arcrola is an instrument developed for the calculation and drawing of large accurate arcs of extensive radii from 4-240 ft. in a matter of seconds, thus eliminating plotting or the use of excessively large beam compasses. By selecting one of the five master discs supplied with the instrument, and suitably adjusting the telescopic scale which he then locks with a set screw, the draughtsman is quickly able to strike the required arc. Triangle Products Ltd.

EMD 1911 for further information



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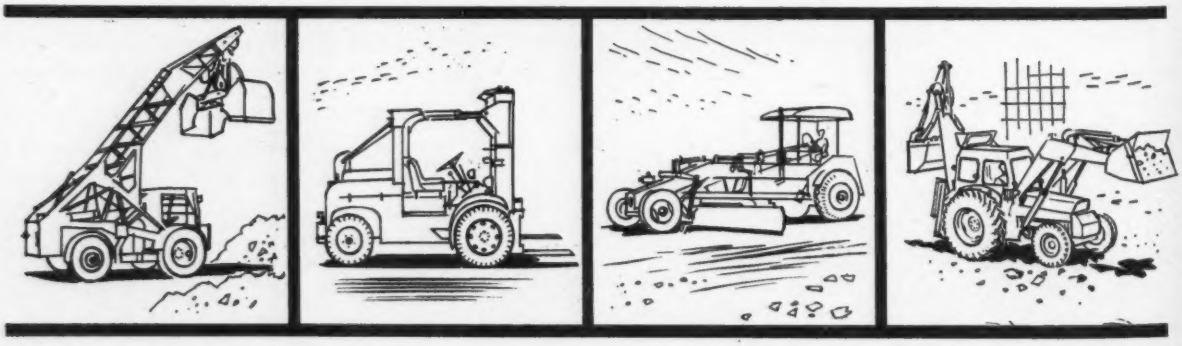

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INDUSTRIAL SALES DEPARTMENT, TRACTOR DIVISION
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News of Industry

Because so many requests have been received by the **Institution of Engineering Designers** for information about careers in engineering drawing offices, they have now produced an illustrated leaflet on the subject entitled *Engineering Design as a Career*. Copies are available free from the I.E.D., 38 Portland Place, London, W.1.

Research and Control Instruments Ltd. are now sole distributors in the U.K. for the industrial products previously marketed by its associated company, Philips Electrical Ltd.

The uses of radioisotopes in industry formed part of an exhibition presented by the **U.K.A.E.A.** in Sheffield earlier this month, and which will be visiting Bradford and Bristol in the near future. Production, processing and application of radioisotopes are demonstrated, and examples shown of radioisotopes used for thickness gauges, radiography and production control, as well as in research.

A 16-mm. sound film has been produced showing many of the highlights of this year's **Electrical Engineers' Exhibition** in London. Copies are available on loan from the A.S.E.E.

At the exhibition held recently in Folkestone in connection with the 1959 national conference of the Purchasing Officers' Association, the award for the best educational display went to **P.I. Castings (Altrincham) Ltd.** The display illustrated the advantages of precision investment castings.

The factory and offices of **Colloidal Graphite Ltd.** have now been moved to Sheaf Island Works, Pond Hill, Sheffield, 1. Telephone number is unchanged.

The **Institute of Welding** recently held a ten-day course for advanced welding engineers. Among the twenty-two lecturers were Prof. N. Rykalin, of the Moscow Academy of Sciences, Dr. H. Krautkramer (international authority on ultrasonic inspection) and Prof. W. Soete, University of Ghent. It is intended to make this an annual course for advanced welding engineers to keep them abreast of latest developments. Subjects covered included modern methods of inspection and problems such as fatigue and brittle fracture.

The **Ultrasonoscope Co. (London) Ltd.** have just delivered to India the first automatic test rig for the ultrasonic inspection of turbine discs. It will be the first of its kind supplied to that country.

The rig consists of an immersion tank containing a turntable to carry the components being tested; this can revolve at continuously variable speeds from 0-20 r.p.m. The drive to the gantry is linked through a gearbox to the turntable so that it advances one step for each revolution of the turntable. In operation the disc under inspection is rotated on the turntable under a probe which moves in radial steps to cover the whole surface to be inspected. The presence of a constant thickness of couplant (e.g., water or paraffin) between the probe and disc ensures that steady and reproducible results are obtained.

An additional melting furnace has been installed by the **Lennox Foundry Co. Ltd.** because of growing demand for Tantiron corrosion-resistant high-silicon iron. The furnace has a capacity of 200 tons a year.

Business of **Gemec Ltd.** has now been taken over by the parent company, Union Carbide Ltd.

Appleby-Frodingham Steel Co. are installing a tonnage oxygen plant at their Scunthorpe works, and should be in use in about a year. It is designed to produce 100 tons of gaseous oxygen a day of 99·5 per cent purity at 600 p.s.i. gauge and ambient temperature. The oxygen will be for metallurgical and combustion purposes.

A special sub-committee has been set up by the **British Plastics Federation** to prepare specifications for expanded polystyrene products. It is considering initially a specification for expanded polystyrene board for thermal insulation.

The **Institution of Mechanical Engineers** has arranged a symposium on recent engineering developments in automatic control to take place from January 5-7 next year.

Large-scale expansions are due for completion next year at the Cambuslang works of **Hoover (Electric Motors) Ltd.**, where f.h.p. motors are produced.

Wall Colmonoy (Canada) Ltd. have opened a London office at 68a Wigmore Street, London, W.1.

Dr. Norman Loveless, a lecturer in psychology at Queens College, Dundee, has been appointed a consultant to **Smiths Aircraft Instruments Ltd.** He will be concerned with the application of experimental psychology in equipment design.

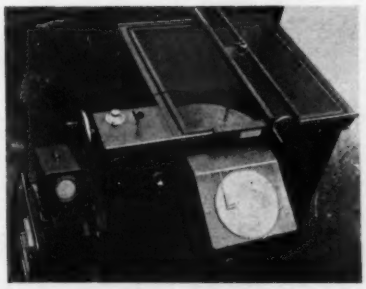
The **Women's Engineering Society** is celebrating its fortieth anniversary this year.

B.I.C.C. Ltd. have formed a U.K. company jointly with the Burndy Corp. of the U.S.A., to be known as **BICC-Burndy Ltd.** The new company will market a wide variety of electrical connectors; among products new to Britain is a forged copper line tap for application in rural electrification.

An interesting feature of the **Mond Nickel Co.** exhibition which has just been held at Southampton was a working model of a rhodium-plating plant. It is the first automatic plant of its kind; it has a capacity of 240 items an hour, handling eight pieces at a time, and completes the plating operation in two minutes. It was built specially for exhibition work.

Switzerland is to become a member country of the **International Institute of Patents.**

A **World Design Conference** is to be held in Tokyo in May next year. The organisers expect some 400 delegates and observers from about thirty countries. A preliminary programme issued recently suggests that the conference will be concerned particularly with fundamental aspects of architecture and industrial design, ergonomics, design education and designer's organisations.



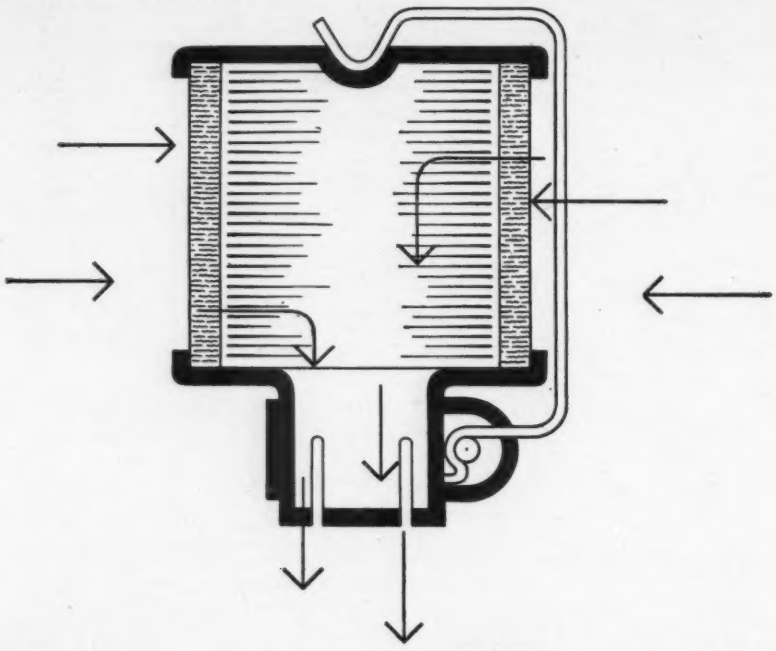
Automatic test rig for testing disc-shaped components, made by Ultrasonoscope Co. (London) Ltd. (See story this page.)

Glass Yarns & Deeside Fabrics Ltd., an associate company of Microcell Ltd., has embarked on a major programme to expand its glass fibre output with a new factory at Camberley, Surrey. As well as producing glass fibre rovings and mat, it will also handle production of new types of fibre.

Because of growing demand for epoxy resins for making tools, patterns, jigs, moulds, checking fixtures, etc. **Shell Chemical Co. Ltd.** have made arrangements for proprietary compositions based on their Epikote resins to be made available for these applications from Beck, Koller & Co. (England) Ltd. and C.V.A. Jigs, Moulds & Tools Ltd. Arrangements have also been made for W. Pickard & Co. Ltd. to supply Epikote-based compounds to the foundry industry.

In a review of exhibits at Farnborough in our October issue, we referred to the filters made by **Vokes Ltd.** as "K.600 Komac". This should have read "K.600 Kompaks".

EMD 1808 for further information



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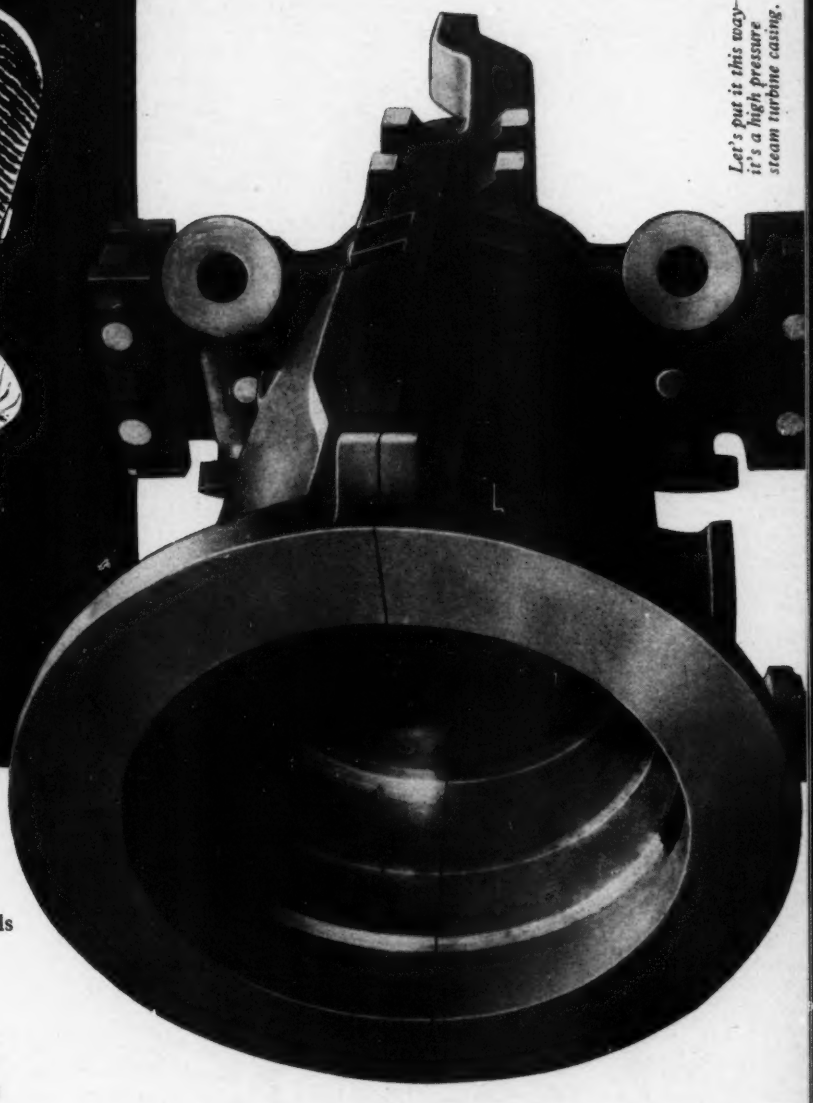
Black Magic

Brown Magic



Let's put it this way—it's a high pressure steam turbine casing.

There is no witchcraft, really, about the unvarying high quality of David Brown castings — though there are many other kinds of craft involved in their production. At the Penistone Foundries, the crafts of the steel maker, pattern maker and moulder are brought together and, with other skills, are co-ordinated into a complex production unit of supreme efficiency. Backed by unique metallurgical resources and using the most up-to-date plant and techniques, this organisation offers a completely reliable service for all types of steel casting.

Next time you have a casting problem, whatever the application, call in David Brown—first!

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If something in the works keeps getting gummed up, sticking, jamming, binding or seizing, don't tie yourself in knots over it. Pass the problem on to us. The answer is probably some form of PTFE, the practically frictionless, non-sticky, corrosion-resistant, insoluble material with wide range thermal stability that we specialise in processing, moulding, extruding, machining, fabricating and applying as a dispersion coating. We can't promise that a PTFE component, lining or surface treatment will be the answer, but we're prepared to tie ourselves in knots to find out for you.
As a start, write for our booklet about SIEMENS EDISWAN PTFE, or ask for one of our staff to come along and talk about it.

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Speed reduction problems are most part solved when you call in David Brown. Take the RADICON for example, did you know there are 270 standard models of this popular speed reducer, sizes 2¼ to 28, available for despatch within 24 hours? In the smaller sizes because demand is so great, delivery is a little longer.

RADICON speed reducers, efficient, silent in operation, are used for those jobs where failure is an unspeakable crime. All over the world engineers are specifying RADICON by name—the finest speed reducer available.

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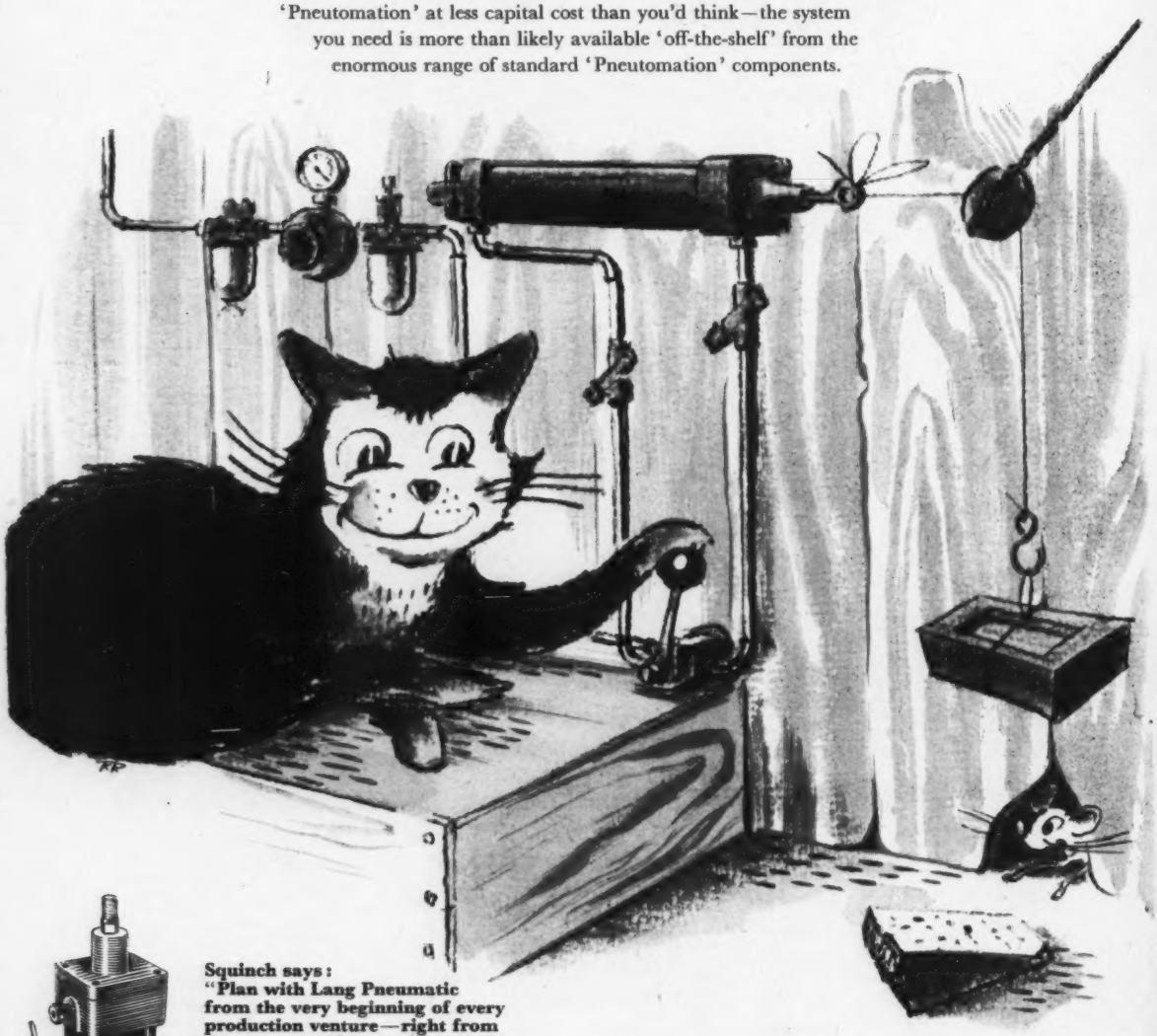
There's a 'situation vacant' in every firm for the tough, willing worker who never tires, never makes an error, will tackle anything—in short, 'Pneutomation'. 'Pneutomation'—Lang Pneumatic air-power systems—is the guiding hand behind a host of jobs from jig-boring to bell-ringing, providing accurate, low-cost control of complex or simple operations. You can enjoy the benefits of 'Pneutomation' at less capital cost than you'd think—the system you need is more than likely available 'off-the-shelf' from the enormous range of standard 'Pneutomation' components.



Squinch says:
"Plan with Lang Pneumatic from the very beginning of every production venture—right from the start, you'll be certain of the happy ending!"

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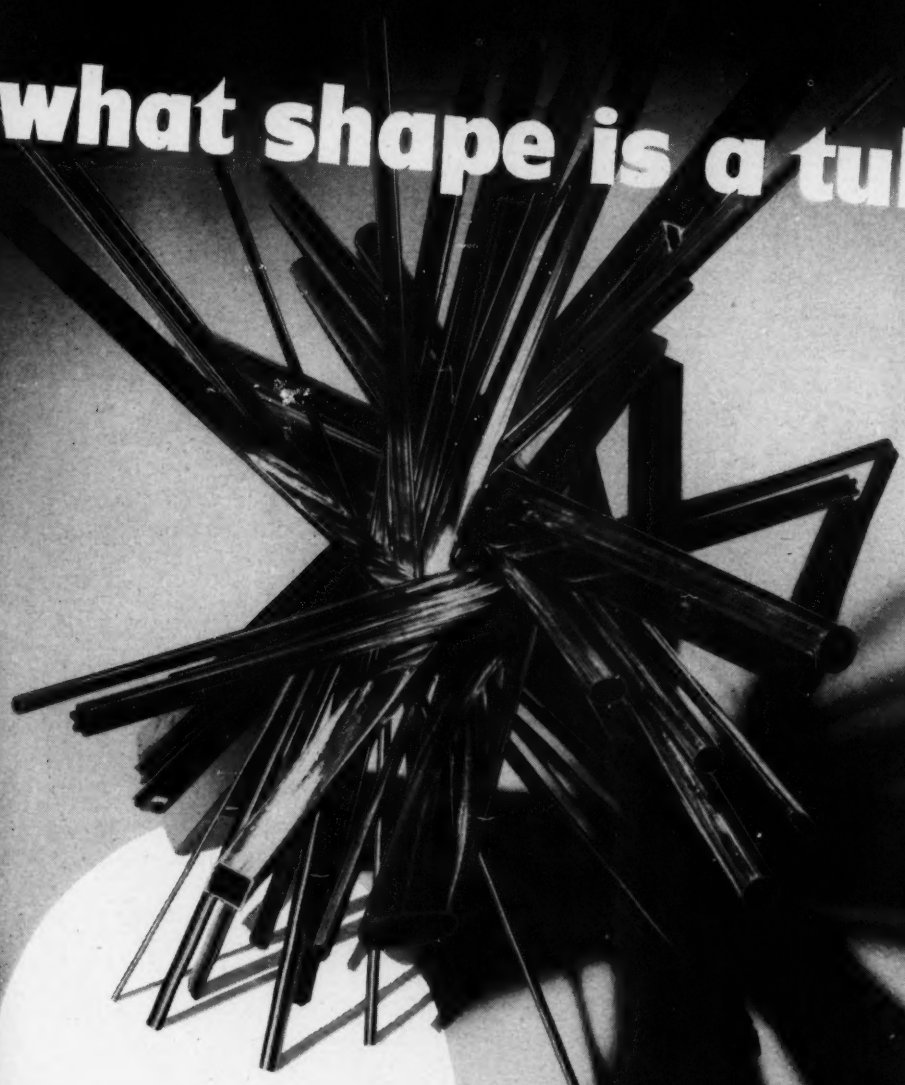
P3429

what shape is a tube...?



... a question, this, that has no single answer, for today industrial requirements for tube products are extremely varied.

To serve the needs of certain branches of engineering, where accuracy of composition and of dimensions are of more than ordinary importance, Johnson Matthey specialise in tube production, bringing to this work both metallurgical knowledge and long experience of tube manufacture by precision methods.

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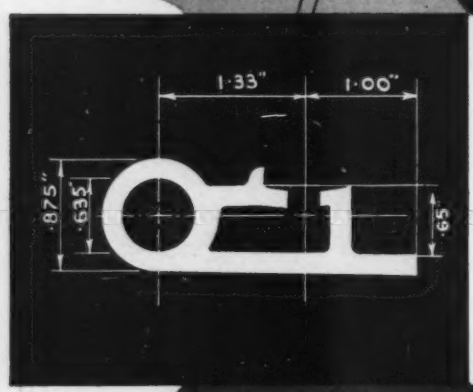
BIRMETALS EXTRUSIONS will make light work of your DESIGN problem



sketch dimensioned section here

241

Finished shapes of all kinds can easily be made as extruded sections in Birmetals aluminium alloys. Sketch your dimensioned outlines in the space next to our example, type your name and address in the margin, send the whole page to us, and we shall be pleased to quote you without obligation.

Would you like a copy of our catalogue of standard sections?

Birmetals

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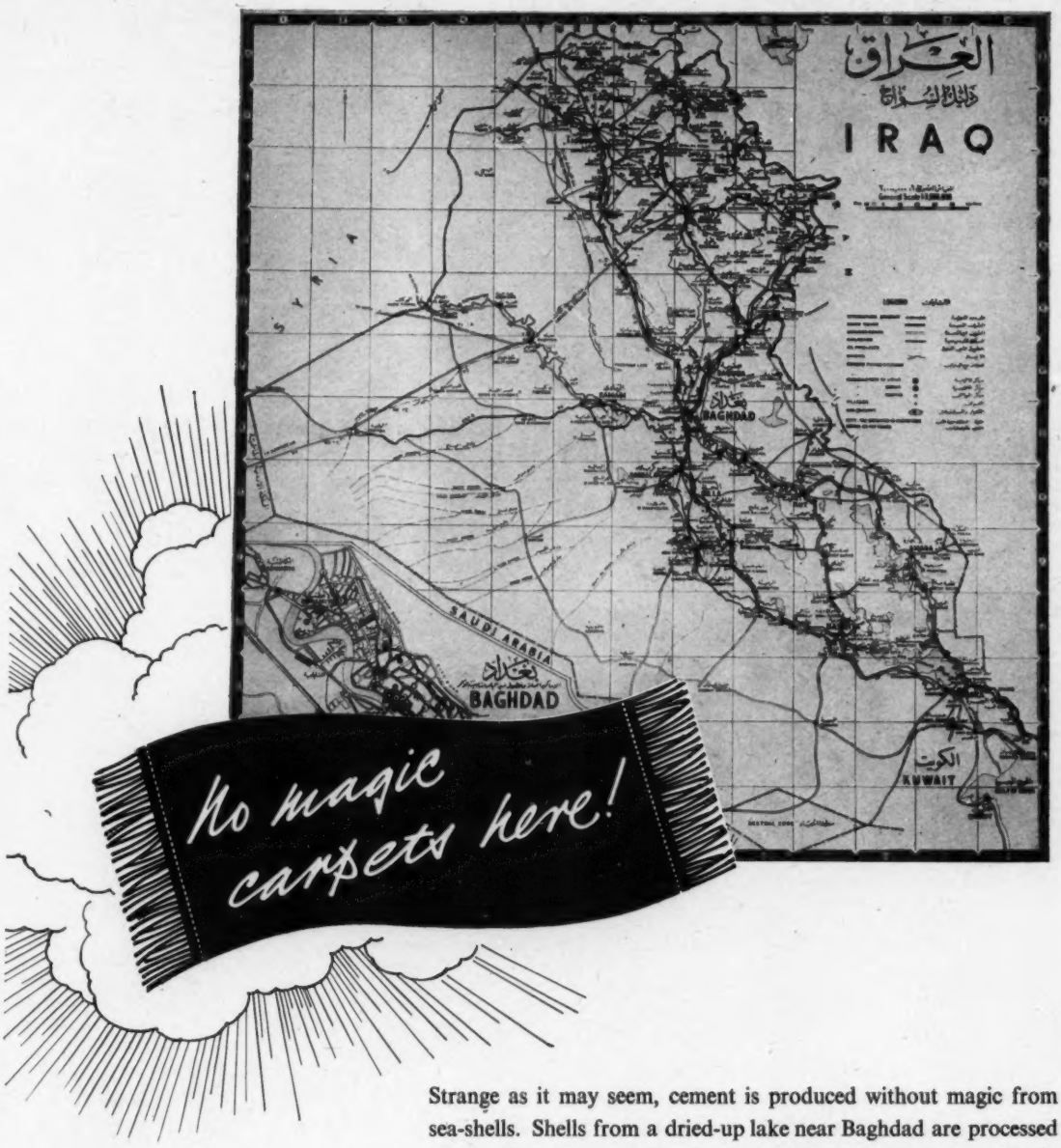

Strange as it may seem, cement is produced without magic from sea-shells. Shells from a dried-up lake near Baghdad are processed by the Iraq Cement Co. for the calcium carbonate needed in cement manufacture. Edgar Allen & Co. Ltd., Sheffield, supplied a primary crusher, a 275 ft. rotary kiln, and two 40 ft. combination tube mills for both wet and dry grinding for this plant. You too can profit from Edgar Allen & Co. Limited's experience in the supply of cement-making equipment.

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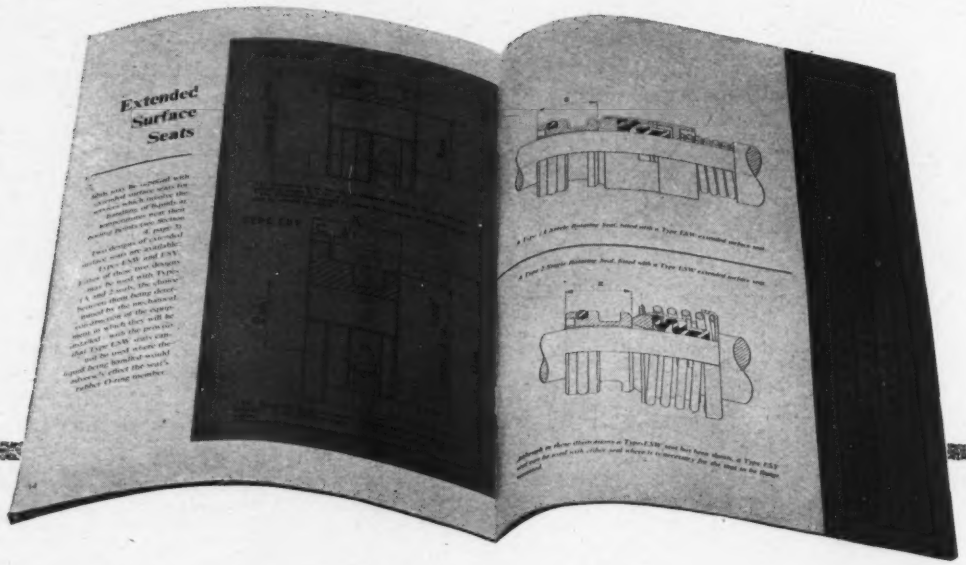
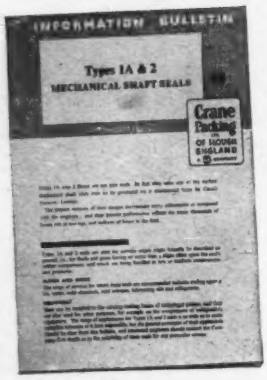


Mechanical Seals *Engineering* at its Best



These are General Purpose Mechanical Shaft Seals. That is to say, they have been designed for service conditions in which corrosive action, temperatures and pressures are not so pronounced as to call for one or another of our purpose-designed seals which are constructed with specially selected materials.

Both Types 1A and 2 Seals have been run for many thousands of hours in service, and their efficiency and reliability have been fully established.

This Information Bulletin, No. 18, contains a comprehensive description of the two seals and of the services for which they are recommended. There are also tables of sizes and other data, and a section is devoted to the newly developed extended surface seats, reference to which has recently been made in the editorial columns of technical journals.

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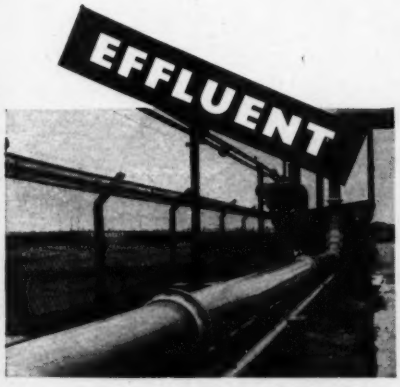

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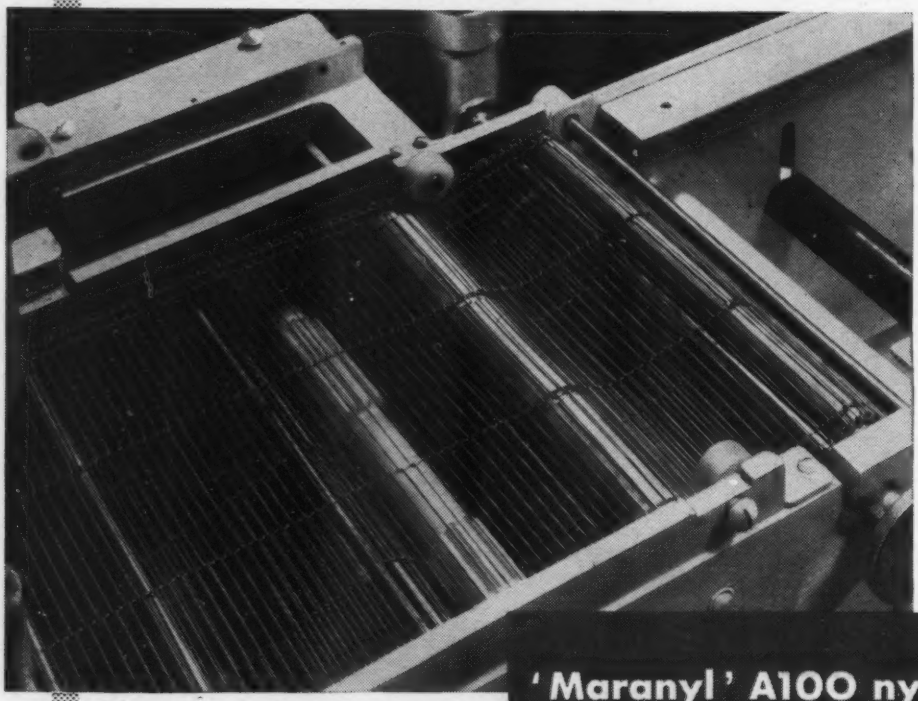

Chocolate enrobing machine made by Sorensen Bakery Equipment Ltd. showing spline drive made from a solid 'Maranyl' nylon bar. Bearings in this machine were made from 'Maranyl' A 100 nylon by Textile Mouldings Ltd.

'Maranyl' A100 nylon makes this chocolate enrobing machine's bearings and gears tough, quiet, long-lasting

BEARINGS AND GEARS made from 'Maranyl' A 100 nylon are tough, light and need no lubrication. They are silent in operation and resist vibrational fatigue.

These properties make 'Maranyl' ideal for bearings and gears in the chocolate enrobing machine shown here, made by Sorensen Bakery Equipment Ltd.

In addition to these important features 'Maranyl' A 100 has many other important properties which give it a multitude of uses in industry today—and tomorrow. It resists oils, fuels, greases and most common solvents. Its coefficient of friction is low. It is shock resistant, easy to fabricate and is available in a wide range of colours.

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'Maranyl' A 100 nylon is backed by the full force of I.C.I. research and technical service. That service is available to you. If there is anything you would like to know about nylon its uses; if you have a manufacturing problem concerning noise, lubrication, wear and durability—get in touch with I.C.I. They'll be glad to help.

'Maranyl' A 100 NYLON

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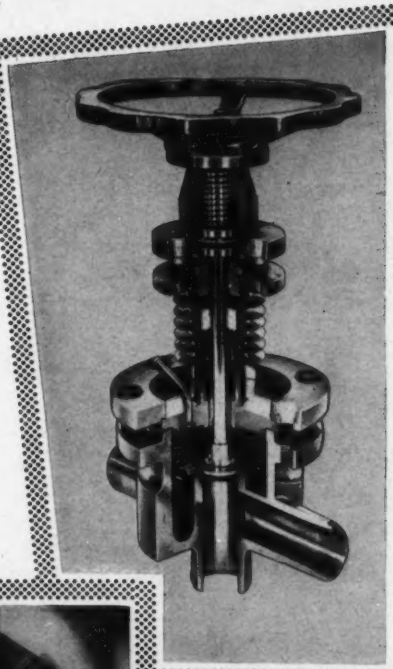
"STELLITE" PROTECTS . . . .

equipment subjected to CORROSION, HEAT and ABRASION

"Stellite" is applied by all welding methods and by spray fusing. It is also available as castings machined to a high degree of accuracy or as precision investment castings.



"Stellite" trim is specified by valve users for applications requiring maximum resistance to heat, corrosion and erosion.

Illustration: Liquid Metal Valve with "Stellite" plug, by permission of Palatine Tool & Engineering Co.

The resistance of "Stellite" to seizure and oxidation, together with its high creep strength is proving invaluable for components used in gas turbines.

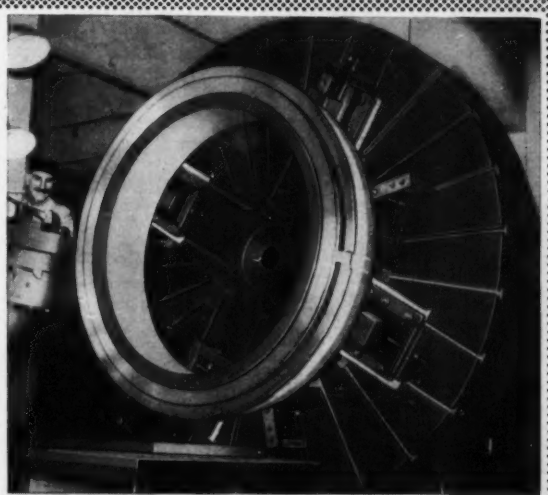
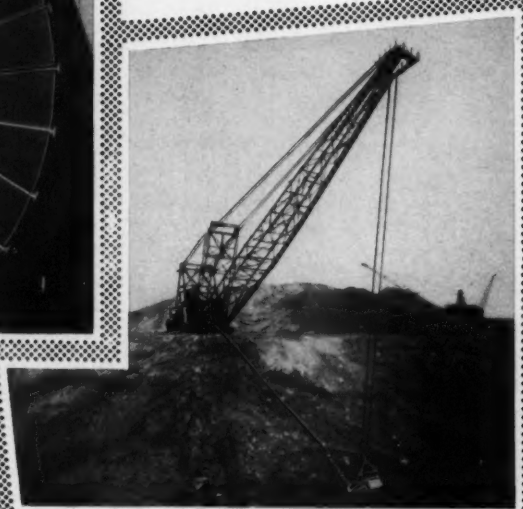


Illustration: Machining "Stellite" faced gas turbine hot ring in the Works of Cantieri del Tirreno, Italy.



The severe abrasive conditions encountered in mines and quarries are successfully combated by facing wearing parts with "Stellite".

Illustration: Excavating on coal site. "Stellite" is used on bucket edges and teeth.

Literature on "Stellite" alloys is available on request.

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DELORO STELLITE DIV. OF DELORO SMELTING & REFINING CO. LTD. BELLEVILLE · ONTARIO · CANADA

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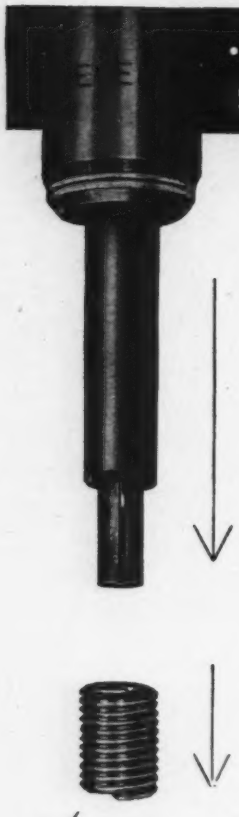
. . . every time this happens someone saves ½d a hole



Readymade self-anchoring female threads inserted at high speed in light alloy materials and plastics. This is the simple process that is revolutionising castings for the secure fastening of non-structural parts.

Heli-Coil Push Type Inserts are metal screw thread inserts that eliminate tapping, solid bushing and the wastage ordinarily involved in working on materials with poor screw thread properties. When the Heli-Coil Insert is used rejects on the assembly line because of faulty threads are something quite unknown.

The Heli-Coil Push Type Insert can be hopper fed and power inserted into the component after moulding, permitting a fast moulding operation. It is a necessity for the automation production line layout. Installation tooling can be had on purchase or rental. May we make an investigation for you?

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Push Type Inserts

The thread you push in

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low cost secure fastening for non-structural parts . . . perfect for the automation production line layout

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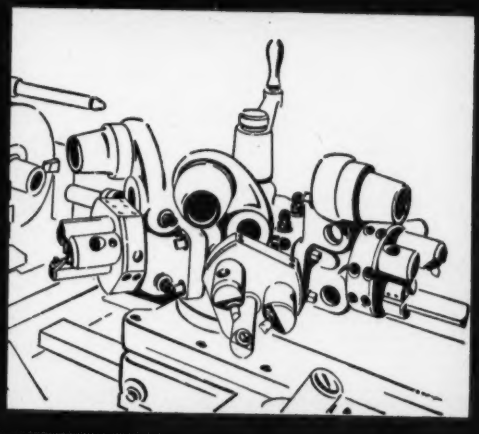
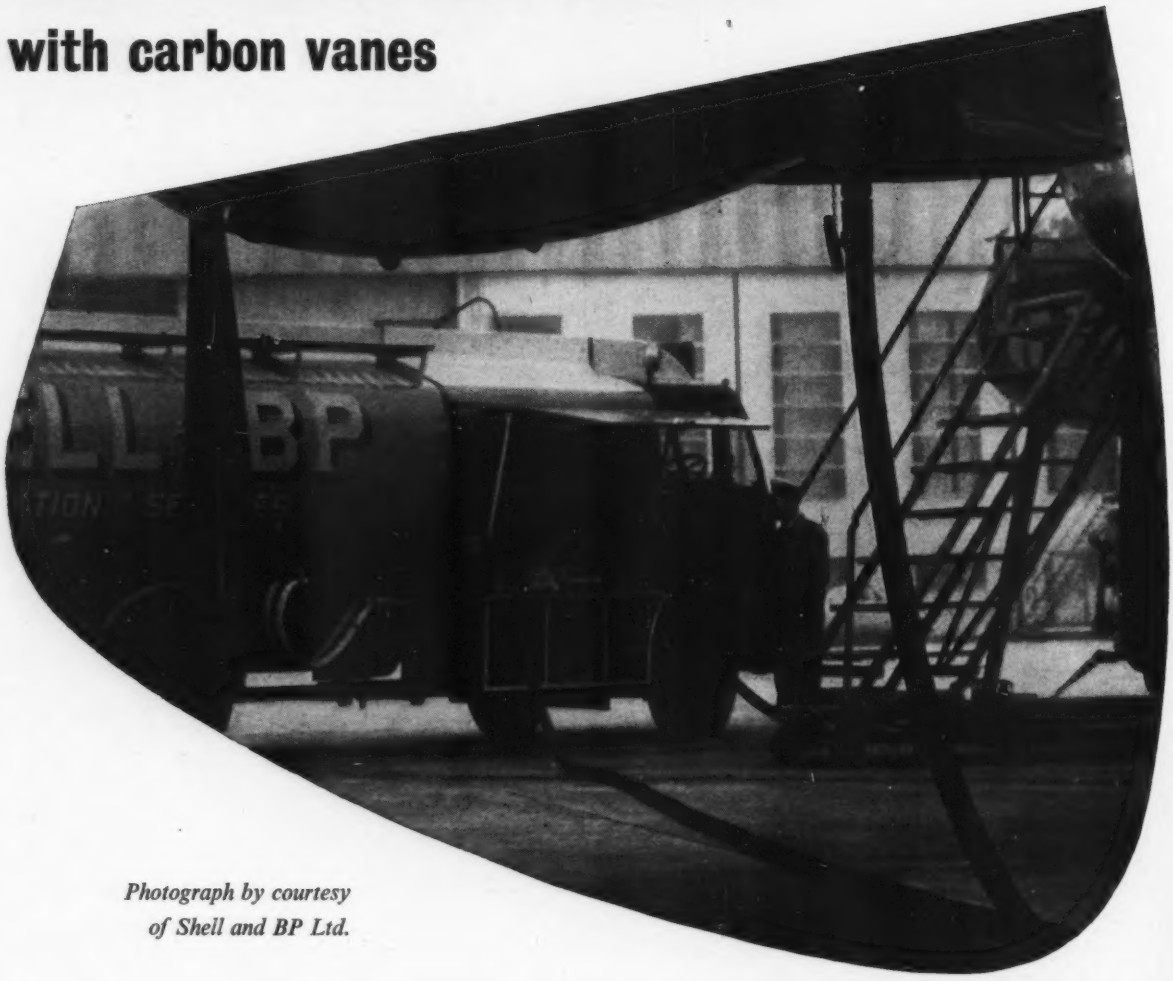


EMD 1760 for further information

SUSTAINED ACCURACY

with carbon vanes



Photograph by courtesy of Shell and BP Ltd.

The refuelling of B.O.A.C.'s Britannia is a routine job for the 4,000 gallon "fuellers" of Shell and BP Aviation Services, and one which demands reliable and accurate equipment. The supply is metered by Avery-Hardoll Bulkmeters, using MORGANITE CARBON VANES.

Impervious to chemical action, strong and highly resistant to wear, MORGANITE CARBON VANES have proved their reliability in action; after many millions of gallons, the accuracy of metering has not varied at all! MORGANITE CARBON VANES solved the problem for Avery-Hardoll Ltd.,—perhaps they will solve yours. Please write or telephone for leaflet SD 69, or for one of our Technical Advisers to call.

MORGANITE CARBON VANES resist chemical atmospheres and corrosive conditions; withstand high temperatures, immersion in liquids; are non-contaminating; need no lubricating; are suitable for inaccessible positions and completely eliminate maintenance.

MORGANITE VANES

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C69A

SMALL COMPONENTS — BIG HEADACHE?

try this simple test!

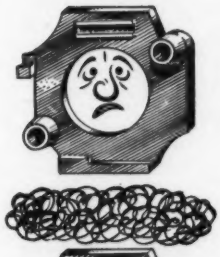
Think of a Shape

—Any shape up to 2½" diameter; not necessarily one like this, but one which might occur to a designer engaged in doing a job.

Complicate it

—Because the basic idea behind a component part must be adapted to serve the function of the whole.

Add further difficulties



—Actually you don't need to add them—they come by themselves! And the original idea often turns out to be a knotty production job.

Cost it for manufacture

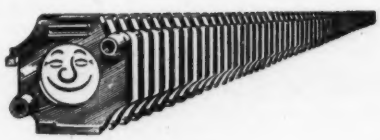
—And pause for gloomy reflection . . . Now what?

THE ANSWER IS AS SIMPLE AS SMC

S M C reduce costs by 40%

The S M C Sintering process saves this amount and more, by eliminating or drastically reducing preliminary machining, riveting, multi-machining operations, finishing (¼ thou. tolerance is obtainable without after-machining) and waste.

S M C manufacture in unlimited numbers



—100,000 is a routine run, and the more you want, the greater your saving. S M C components can be produced in an infinite range of finishes and characteristics, and with a wear-resistance up to SIX TIMES that of hardened steel.

For further information write or call in at

SINTERED METAL COMPONENTS (CHARD) Ltd

BODEN WORKS CHARD SOMERSET

Chard 3212. *A member of the Sterling Industrial Group*

J.W.Ad 4726

Bronze

for hard wear and low friction

Holfos is a bronze made only by Holroyd. We first brought it out thirty years ago and since then we have constantly been improving and perfecting the technique of its production.

Its use is a distinct contributory factor to the high efficiency and sturdy performance of Holroyd worm gears and worm gear speed reducers. Holroyd worm gears using Holfos bronze hold the World Record for efficiency as determined by an independent test made at the National Physical Laboratory.

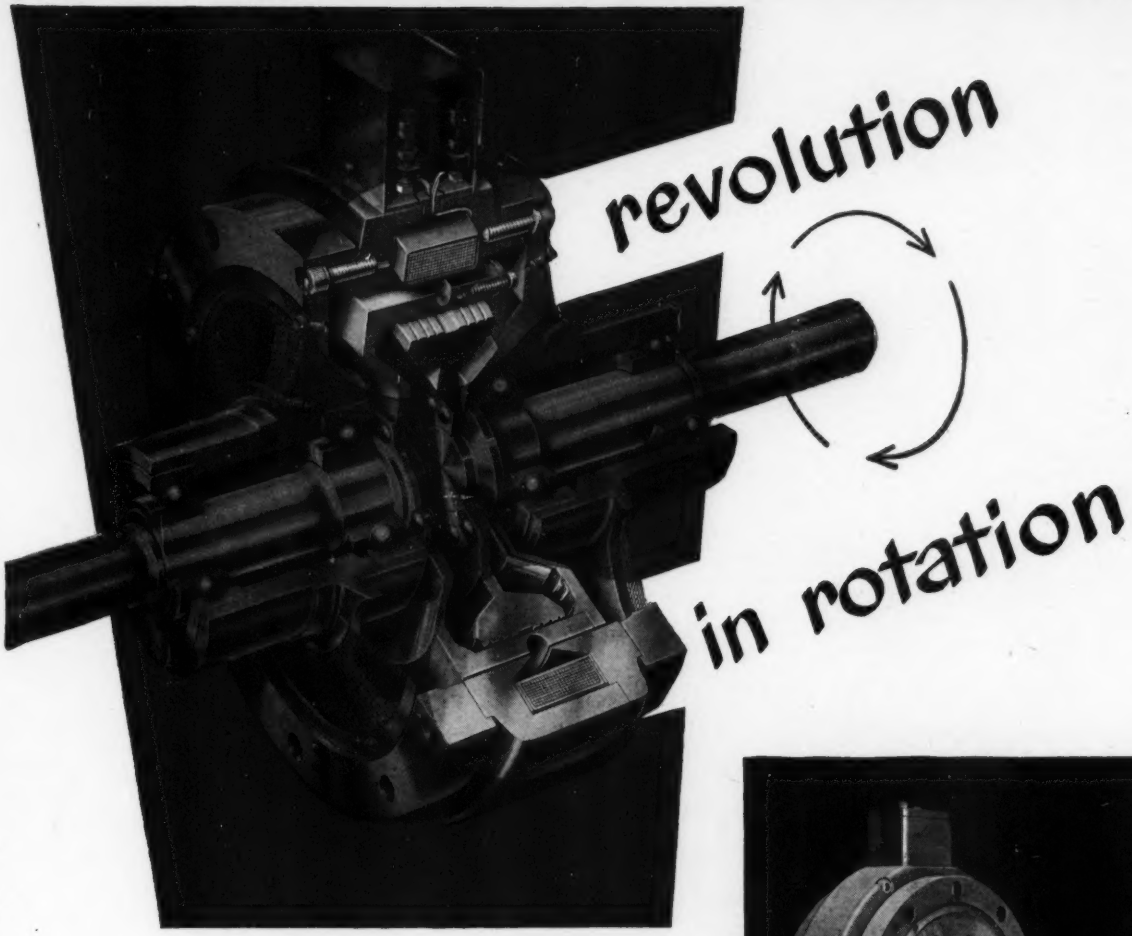
Holroyd

JOHN HOLROYD & CO LTD

HOLFOS WORKS ROCHDALE
(For Castings and Machined Blanks)

PERSEVERANCE WORKS MILNROW
(For Finished Gears)

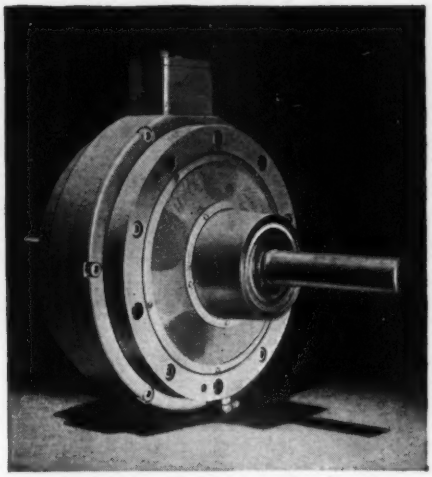
HL 16



SMITHS

Magnetic Particle COUPLING

This is a positive coupling working on a new principle. It is NOT a magnetically operated clutch, and there are no plates to wear.



Driving and driven members are coupled by magnetically activated particles, giving perfectly smooth take-up and accurate control of torque. Eight standard units are made ranging from 1/3 to 200 lb/ft.

SMITHS S. SMITH & SONS (ENGLAND) LIMITED

INDUSTRIAL PRODUCTS DEPARTMENT, WITNEY, OXON Telephone Witney 678

AP183

Do you really think I need bother about **nitrogen?**

Some people do . . .
in free-cutting steels.

ACIBAR and ACIBEL

(non-leaded) (containing lead)

are free-cutting, easy-machining steels produced by the Acid Bessemer process. They contain up to .018% nitrogen which assists in achieving

more rapid machining
improved mechanical properties
better finish

—and their content of residual elements is, of course, consistently low.

WORKINGTON

IRON AND STEEL COMPANY

Workington · Cumberland

a branch of THE UNITED STEEL COMPANIES LTD

W118

EMD 1765 for further information

Here are further

Excellent Examples of ALZEN 305 Bearing Applications

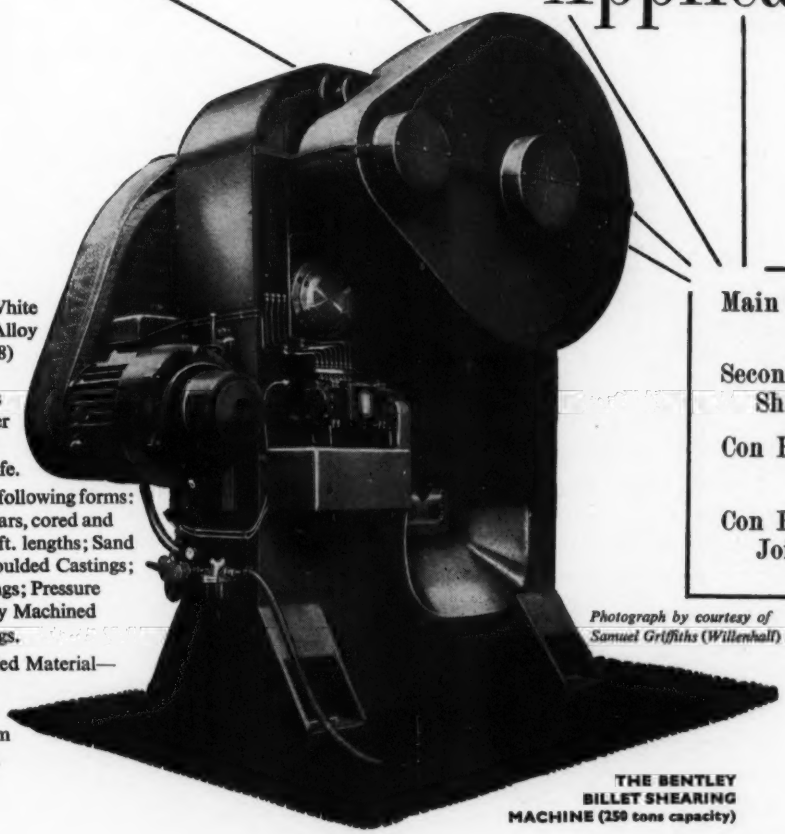
ALZEN 305

Reg. Trade Mark B 752748

Alzen 305 is the White Bronze Bearing Alloy (British Pat. 725818) that reduces the weight of bearings by half, saves 40 per cent. of cost and lengthens bearing life.

It is supplied in the following forms: Ingot; Chill Cast Bars, cored and solid, in approx. 2 ft. lengths; Sand Castings; Shell Moulded Castings; Gravity Die Castings; Pressure Die Castings; Fully Machined Bushes and Bearings.

Also Alzen Extruded Material—specified as Alzen 305K Bar—Solid or Tube in random lengths of 10/12 ft.



THE BENTLEY BILLET SHEARING MACHINE (250 tons capacity)

Main Crank Shaft Bearings

Secondary Motion Shaft Bearings

Con Rod Big End Bearings

Con Rod Knuckle Joint Bearings

Photograph by courtesy of Samuel Griffiths (Willenhall) Ltd., Willenhall, Staffs.

May we send you technical data and samples for testing

HILL ALZEN (SALES) LTD., P.O. BOX 22, Stringes Lane, Willenhall, Staffs.

Telephone: WILLENHALL 227 (5 lines) Telegrams: Hill, Alzen 227 Willenhall

WhiteAd 4108

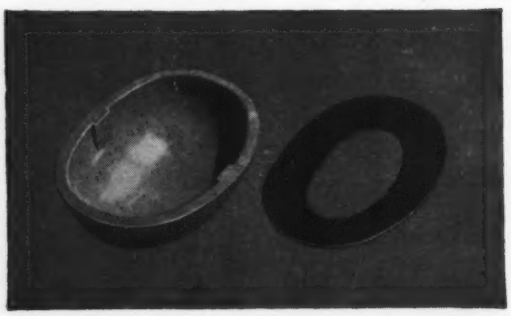
EMD 1766 for further information

Here's a typical example of how the mechanical strength of Beetle D.M.C. (Dough Moulding Compound) helps to solve industrial problems.

These ear defenders are used to protect the hearing of workers in proximity to jet engines and in noisy factories. During the development work by the makers, Dennis Ferranti Meters Ltd., twelve sets moulded from conventional materials were delivered to Bomber Command for testing. The report of The Central Medical Establishment, Acoustics Laboratory, was that the ear defenders gave excellent protection, but that the mouldings then used were considered too fragile.

D.M.C. mouldings were substituted and have been found virtually indestructible.

D.M.C. is the ideal material whenever high mechanical and/or electrical strength is required. The material can be moulded in conventional compression presses on short cure times and at low pressure. We shall be glad to send full technical details.



This illustration shows the main moulding from Beetle D.M.C. and a retaining piece made from Scarab material. The Earguards are used in engine testing, rivetting, blasting, rolling mills, weaving sheds, paper mills and on aerodromes.

B·I·P

BEETLE MOULDING POWDERS

B.I.P. CHEMICALS LTD., Oldbury, Birmingham. Telephone: Broadwell 2061.
London Office: 28 Haymarket, London, S.W.1. Telephone: TRAfalgar 3121

EMD 1767 for further information

cast in steel

at 14% less cost

– with greater rigidity and improved appearance

To reduce the cost of manufacture, whilst measuring up completely to the arduous conditions of service on Jones Cranes, this worm gearbox cover was remade as a steel casting in a modern steel foundry.

Compared with the previous method of production, this change gave a cost reduction of 14% on each cover, gave greater rigidity and, with the design freedom afforded by casting, gave improved appearance.

Why not meet your problems in the most economical way—take advantage of steel foundry know-how and call in a steel foundry engineer at the design stage.

THE BRITISH STEEL FOUNDERS ASSOCIATION

Broomgrove Lodge, Broomgrove Rd., Sheffield

BSFA STEEL CASTINGS

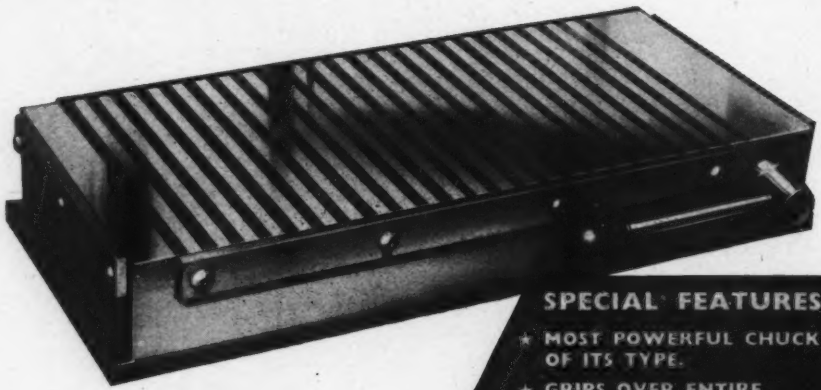
EMD 1768 for further information

DARWINS

FMAX

PERMANENT MAGNET RECTANGULAR CHUCKS

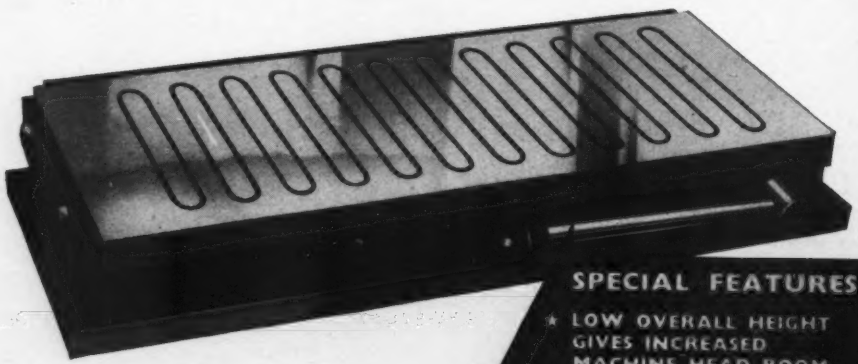
THE FINEST AND MOST COMPREHENSIVE RANGE OF PERMANENT MAGNET CHUCKS AND ACCESSORIES AVAILABLE



"F" TYPE CHUCK

SPECIAL FEATURES

- ★ MOST POWERFUL CHUCK OF ITS TYPE.
- ★ GRIPS OVER ENTIRE SURFACE.
- ★ RAPID COUPLING FOR GANG CHUCKING.
- ★ POWERFUL SIDE GRIP FOR PRECISION SQUARING.



"D" TYPE CHUCK

SPECIAL FEATURES

- ★ LOW OVERALL HEIGHT GIVES INCREASED MACHINE HEAD ROOM.
- ★ CLOSE POLE SPACING.
- ★ INTERNAL STRUCTURE GIVES EXTRA RIGIDITY AND SUPPORT TO THE TOP PLATE.

Write for literature to Darwins Magnetic Tool Division

DF 100

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A PRODUCT OF THE DARWINS GROUP

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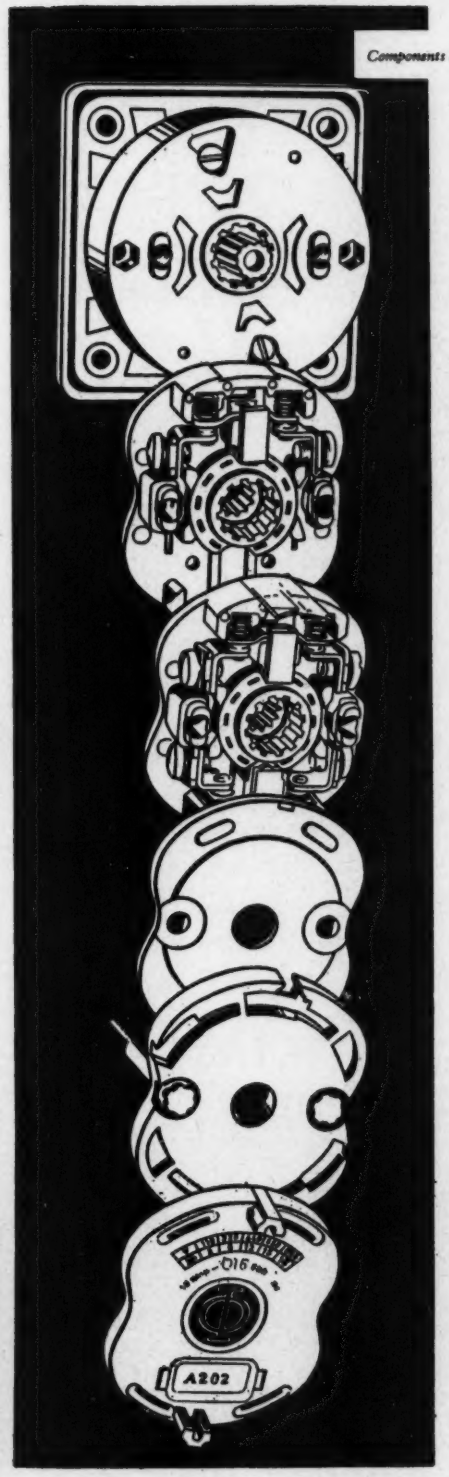
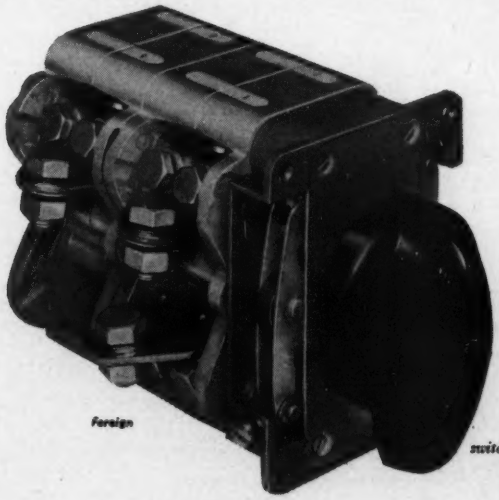


Components of 16 amp switch with up to 18 latching positions

STANDARDIZED TO THE Nth DEGREE

Style C-Switches are standardized to an extent never previously achieved in switch design. Perfection of moulding permits each switch to be built up from a series of prefabricated sub-assemblies. By using appropriate operating cams, any practical contact arrangement can be provided by standard units, so that prices are kept low. Each contact unit carries two double-break silver alloy contacts, and any number up to twelve stages can form a single column; additional stages to be operated by the same control are arranged as extra columns, and are operated in tandem. Switches of different carrying capacities may be coupled if required. Escutcheon plates and control handles are common to the whole range. These switches are available in five ratings, from 16 to 200 amp at 600 volts a.c.



200 amp 12 position switch for panel mounting

style C-switches

Full particulars from the Distributors for the United Kingdom and Eire

CHILTON

CHILTON ELECTRIC PRODUCTS LIMITED
HUNGERFORD, BERKS. Telephone: Hungerford 237/238
London Office: 19 Old Queen Street, S.W.1 Telephone: TRAfalgar 2230

EMD 1770 for further information

Designing any of these?

TANKS AND VESSELS

PIPE INSTALLATIONS

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OR ANY TYPE OF CHEMICAL PLANT

Then you should know these facts about RUBBER LININGS

Ninety per cent of corrosion or abrasion resistance problems can be solved by the use of rubber linings.

In cost, application and maintenance, rubber is the most economic of the corrosion and abrasion resistant materials.

Vulcanised natural rubber compounds are resistant to most inorganic acids, alkalis and salt solutions. They will withstand very many organic chemicals but are not suitable for use with mineral oils or oxidising agents (for which there is a range of synthetic rubbers).

Soft rubber compounds are widely used under corrosive and *abrasive conditions.*

Natural rubbers can be compounded to combine flexibility and impact resistance with anti-corrosive properties. They can be applied where the lining is subjected to mechanical shock or thermal changes.

Ebonite has the highest chemical resistance of all the natural rubber compounds. It also has excellent machining properties.

Synthetic rubber compounds are available with high resistance to acids, acid fumes and mineral oils. Some are suitable for use at unusually high operating temperatures.

The bond formed between rubber linings and metal during vulcanisation has a strength of at least 2000 p.s.i., making them eminently suited for use under vacuum conditions.

Rubber linings can be applied either at the liners' works or on site, according to the size and complexity of the job. Installations lined on site can be of metal, concrete, timber or brick construction.

90% OF YOUR CORROSION AND ABRASION PROBLEMS CAN BE SOLVED BY RUBBER LININGS

PLANT LINING GROUP
P·B·R·A·M
RUBBER–EBONITE

Full technical information is readily available from any of the following members of the
PLANT LINING GROUP
Federation of British Rubber and Allied Manufacturers

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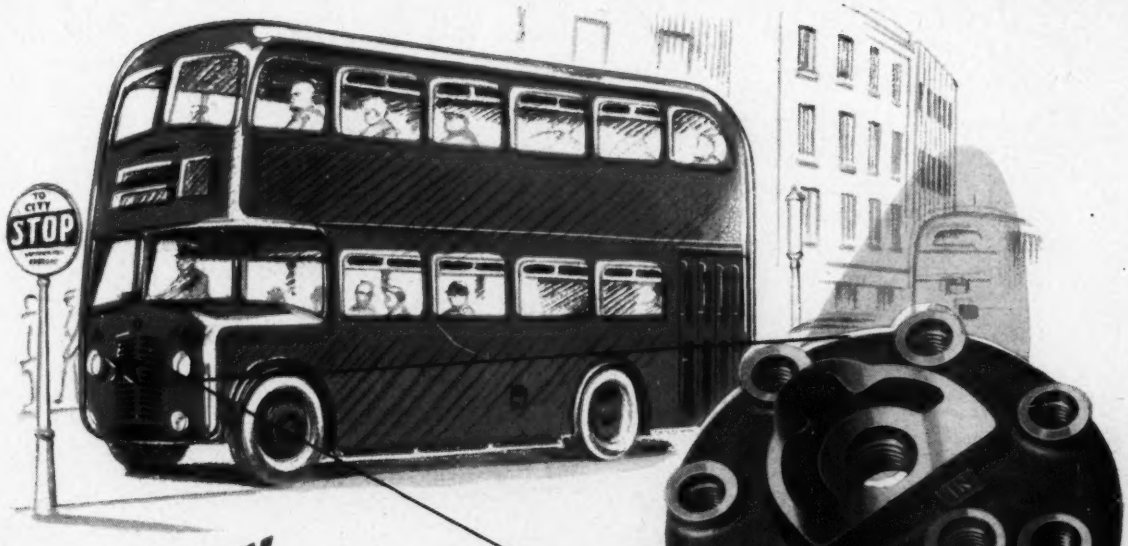
DEXINE RUBBER COMPANY LTD., Rochdale, Lancs.

DUNLOP RUBBER CO. LTD., G.R.G. DIV., Manchester, Lancs.

NORDAC LIMITED, Uxbridge, Middlesex.

REDFERNS (BREDBURY) LTD., Bredbury, Nr. Stockport.

ST. HELENS CABLE & RUBBER CO. LTD., Slough, Bucks.

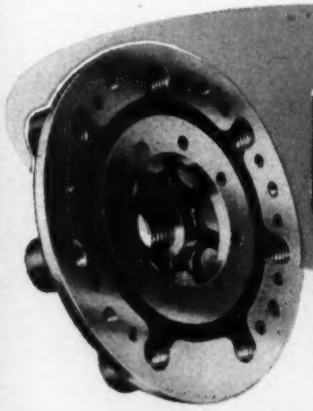


WHEN SAFETY MEANS SO MUCH

P·B·M CASTINGS ARE USED ...

No vehicles make more constant use of braking power than Public Transport. That's why, when constant reliability is so vital, P·B·M Aluminium castings are specified by Lockheed for the hydraulic pump on their famous power-operated brakes in use on the buses of Midland Red Motor Services—one of the largest services in the country.

This core, weighing less than two ounces, used in the production of these hydraulic pump castings, symbolises the intricacy and fineness of this high quality production.



PBM GRAVITY DIECASTINGS

MACHINED CASTINGS & ASSEMBLIES . . .

P·B·M have excellent facilities for supplying castings as fully machined and assembled components.

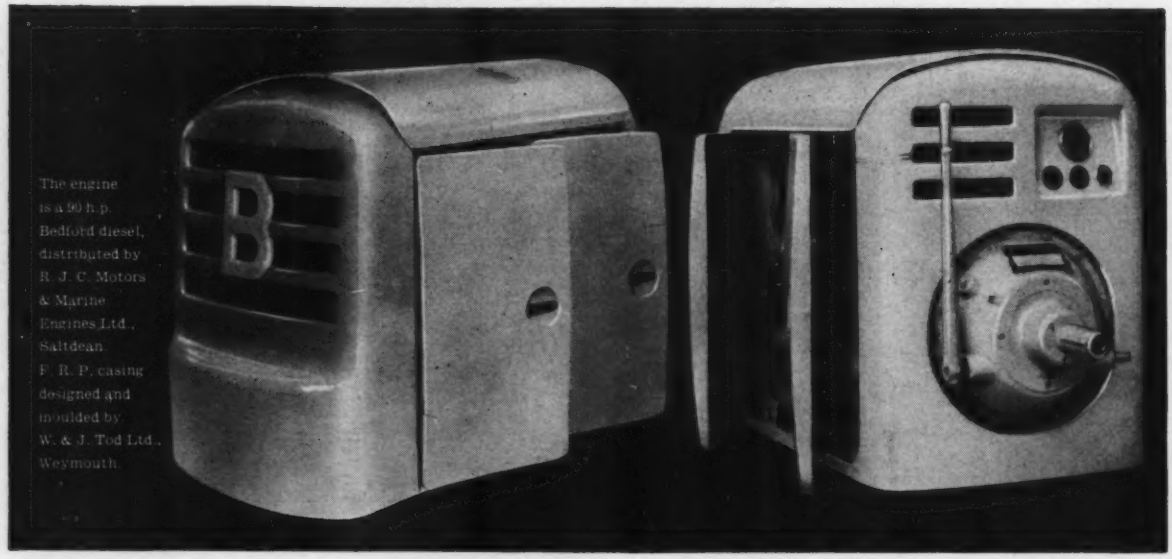
PERRY BARR METAL COMPANY LTD., GREAT BARR, BIRMINGHAM 22A

TELEPHONE: GREAT BARR 1794-5-6

EMD 1772 for further information

"So pleased with the results and appearance that it was immediately ordered into production"

Extract from a report on this engine casing in Fibreglass Reinforced Plastics.


The engine is a 90 h.p. Bedford diesel, distributed by R. J. C. Motors & Marine Engines Ltd., Saltdean.
F. R. P. casing designed and moulded by W. & J. Tod Ltd., Weymouth.

Engine casings were needed. The alternatives: moulding in F.R.P. or shaping in metal. The choice: F.R.P. This is why.

F.R.P. is light yet strong; it can, as in this case, be self-coloured, needing no painting or maintenance; it is unaffected by exposure to the weather and does not drum; it can be moulded easily and styled attractively. Finally, F.R.P. is highly resistant to most forms of corrosion—including the sulphur fumes given off by diesel fuel.

Would these advantages apply in *your* case, for *your* product? The answer may well be 'yes'; but ask us and we will tell you—without obligation and without bias.

FIBREGLASS TRADE MARK **the backbone of Reinforced Plastics**

Our advisory service is expert, confidential and free

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Tough as the rock

COR-TEN CAN TAKE IT

Super-tractor shovel shifting rocky overburden (Photograph by courtesy of Michigan (Great Britain) Limited)

WHEREVER you see steel taking savage punishment, the chances are it will be SCW Cor-Ten from The Steel Company of Wales.

With good reason. For over the past four years SCW Cor-Ten has built up a solid reputation for sheer toughness. More and more designers and users are specifying SCW Cor-Ten where high yield strength and corrosion and abrasion resistance are of major importance.

Cor-Ten is tougher

- Weight for weight, the yield strength is 50% higher than ordinary mild steel
  alternatively: Strength for strength, a saving of ⅓ of the weight is possible
- 4-6 times more resistant to atmospheric corrosion
- Highly resistant to abrasion and fatigue

Please write to us at the address below for further information or for technical assistance in the application of SCW Cor-Ten to your products

S·C·W BRAND Cor-Ten

RAILWAY ROLLING STOCK
AGRICULTURAL AND EARTH-MOVING EQUIPMENT
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There are now over 600 Spire Speed Fastenings!

Most people use Simmonds Spire Speed Fastenings, but the range is growing so fast that you can't be expected to keep track of the latest additions. We probably have the answer to your present assembly problem. Send us particulars of any fastening difficulties you are up against or let one of our *fastening specialists* come along and discuss your problems on the spot.

Spire

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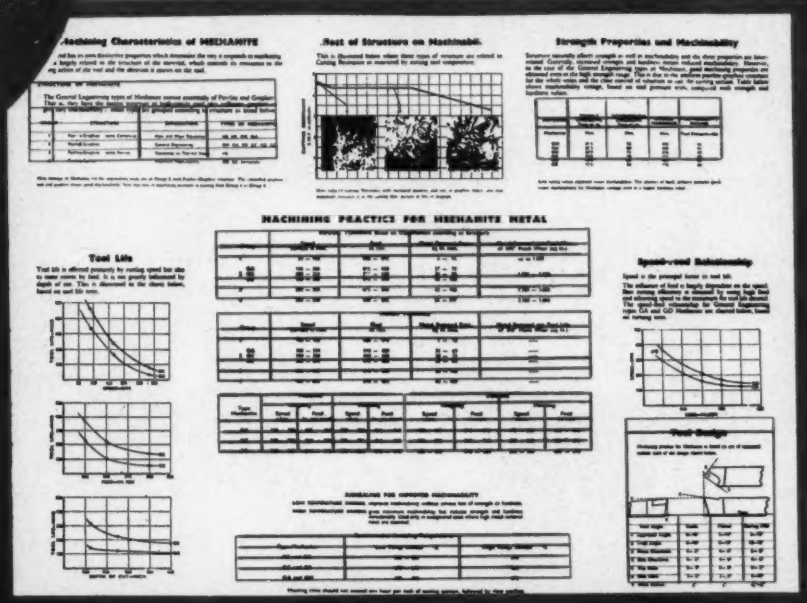
A MEMBER OF THE FIRTH CLEVELAND GROUP

CRC 513

a 'must' in every machine shop

MEEHANITE MACHINING CHART



A welcome addition in every machine shop is the MEEHANITE Machining Wall Chart.

This two-colour chart (28" × 22") is packed with valuable information on recommended machining practice for the various cutting operations, data on tool design, the relation between speed, feed and tool life, etc. It is essentially practical in that it can be interpreted directly by the machine shop into operating practice.

Write for a FREE copy of MEEHANITE Machining Chart M6.

specify MEEHANITE for better iron castings

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EMD 1775 for further information

EMD 1776 for further information

..."have you thought of Silver Brazing?"

Whenever you face the problem of how to join one metal part permanently to another, think of silver brazing—for it is often the best method.

Great strength and neat finish are features of this modern process, and when the higher temperatures required for welding or spelter brazing may bring danger of distortion or loss of metal temper, low temperature silver brazing often provides the perfect solution—and the perfect joint.

Technical data sheets covering all aspects of the technique of silver brazing are now being published. May we add your name to our mailing list?

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EMD 1777 for further information

the embodiment of this scientific age

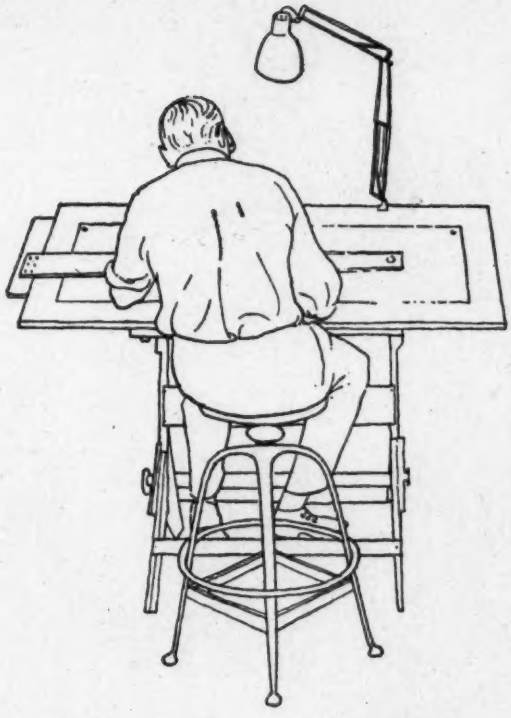
Forward-looking engineers are embodying Heli-Coil Screw Thread Inserts in their designs because competition demands that they use only today's most advanced and successful techniques.

The Heli-Coil method of screw thread engineering can improve products in almost an infinity of ways . . . and at the same time make dramatic cuts in time and labour costs. It is ideal for automation, the operation is simplicity itself, just drill, tap and install.

The Heli-Coil Insert provides a conventional thread with higher loading strengths and greater resistance to wear and stresses—it literally *armours* the thread.

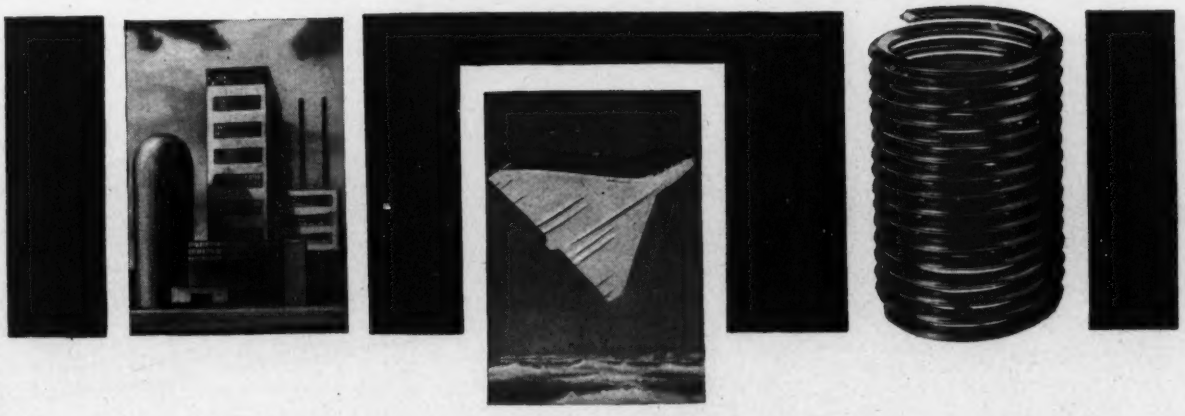
The assembly obtained is anti-vibration because the Heli-Coil Insert allows pre-stressing. Weight and space are saved and the serviceability and appearance of the product enhanced.

The importance of Heli-Coil Inserts to the modern designer is an irrefutable fact. Why not have all the information in front of you—data is freely available. Ask for Sales Leaflet APL 48/E 11.



HELI-COIL*

SCREW THREAD INSERTS



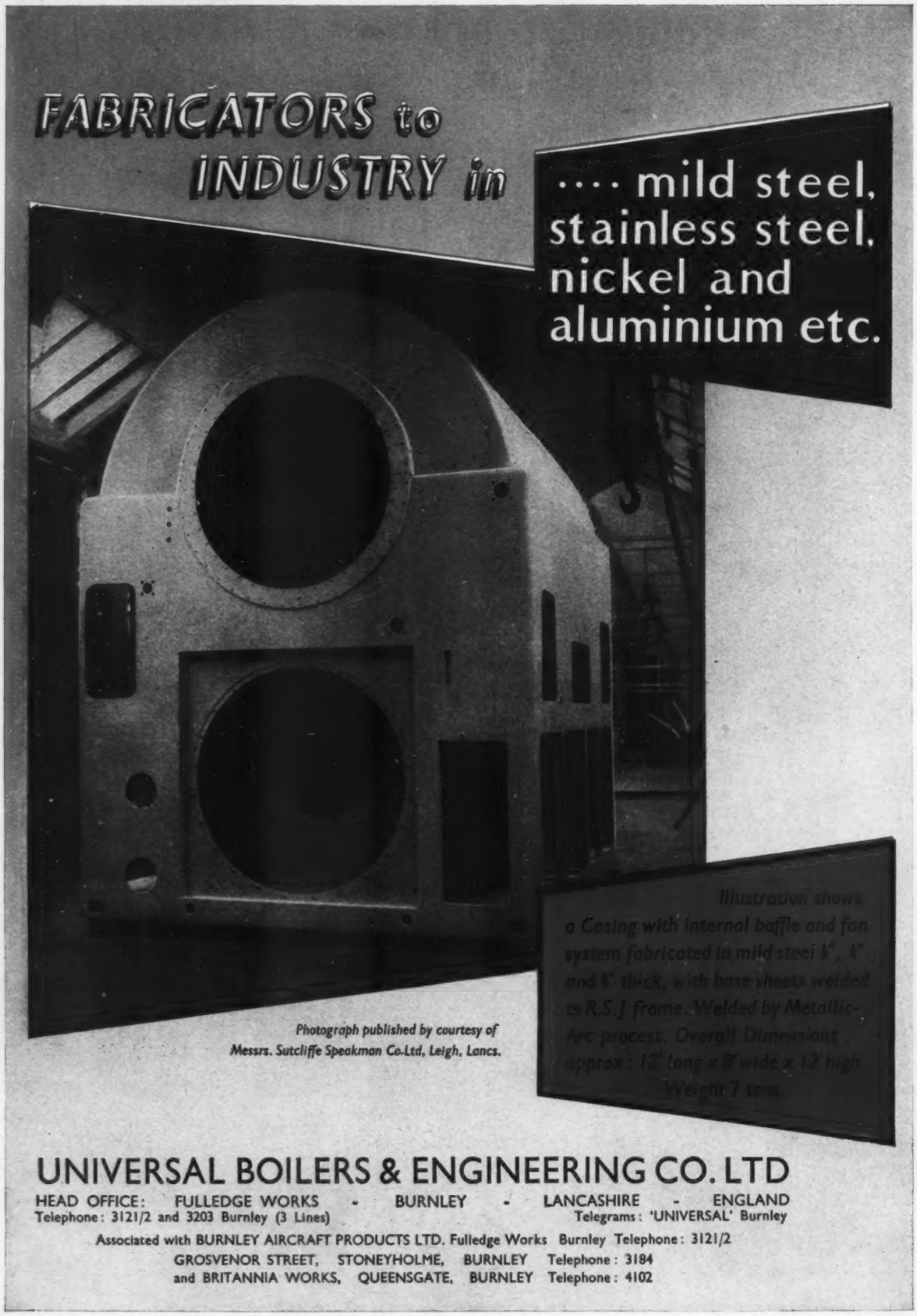
Your newest design . . . is it quite up to date?

*HELI-COIL is a registered trade mark

Write for more data on HELI-COIL inserts to ARMSTRONG PATENTS CO. LTD. EASTGATE, BEVERLEY, YORKS.

Telephone: Beverley 82212 (6 lines)

EMD 1778 for further information


FABRICATORS to INDUSTRY in
.... mild steel, stainless steel, nickel and aluminium etc.
Photograph published by courtesy of Messrs. Sutcliffe Speakman Co. Ltd, Leigh, Lancs.
Illustration shows a Casing with internal baffle and fan system fabricated in mild steel ¼", ⅜" and ½" thick, with base sheets welded to R.S.J frame. Welded by Metallic-Arc process. Overall Dimensions approx: 12' long x 8' wide x 12 high Weight 7 tons.

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the leading polystyrene

the polyethylene plus

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1. the top of the casing in RIGIDEX polyethylene.
2. the lid in STYRON polystyrene.

Each material provides just the properties for the purpose required. Here Rigidex plays the major part. Rigidex will not break, chip or corrode, resists steam, boiling water and detergents, never absorbs water. The stiff Rigidex casing makes an effective seal with the Styron lid assembly. In every kind of power driven domestic equipment Rigidex— the polyethylene plus—the rigid polyethylene— will improve appearance and performance, and enhance sales appeal.

Write now for the Rigidex Booklet No. 317

Standard Spin Drier by Gordon-Miller Ltd. 91 Beddington Lane, Croydon, Surrey.

Rigidex is the reg'd trade mark of British Hydrocarbon Chemicals Ltd.

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FIRTH-VICKERS STAINLESS STEELS LTD., SHEFFIELD

is the only company in Europe to devote its activities exclusively to the production and development of stainless and heat-resisting steels.

The SHAPE of things

A quiet revolution is taking place in the use of materials in Industry.

As the value of first class functional design gains ever increasing appreciation, so the scope of the Industrial Designer becomes wider and his search for new materials more intense.

This is why more and more designers have in recent years turned to Hawley Moulded Fibre with its distinct advantages over most conventional materials in resilience, versatility and strength/weight ratio.

Now an even better material is available to Industry on a production basis. The new Hawley Aqueous Mix Polyester Glass Fibre mouldings, protected by patents in Great Britain and many other countries, offers unlimited scope. Thinner, lighter, yet stronger than ever before and available in a wide variety of attractive finishes, this new and revolutionary material must surely be of interest to all concerned with Product design.

May we send you further information?

These Antler suitcases, handsomely covered with PVC and fitted with a stainless steel section on the edges are a good example of functional design. A pair of plain shells with a glass fibre content weighs approximately 3½ lbs and they have a tensile strength of 7500 lbs/sq. in. and a flexural strength of 9500 lbs/sq. in.

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The Thompson L'Hospied service embodies much more than the production of accurate and consistently fine heat-resisting castings. Through their close association with the furnace industry they have first-hand knowledge of its requirements and unequalled facilities for testing under actual conditions.

Added to these unique advantages is the specialised knowledge acquired during over twenty-five years in the trade. Thompson L'Hospied advice on alloys and design is widely sought and freely given to customers in every industry where heat or chemical treatment plays a part.

Thompson PIONEERS OF T'H HEAT RESISTING CASTINGS **L'Hospied**

A Member of the Incandescent Group

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By designing for Araldite, South Wales Switchgear Ltd. have provided adequate protection for this 3-phase voltage transformer without the use of oil. The coils and insulators form a single casting of Araldite B, simple in design and easy to manufacture. Araldite casting resins do not shrink on setting, and are thereafter unaffected by very wide changes of temperature and humidity. Their properties also include remarkable adhesion to metals, ceramics, etc., high mechanical strength, freedom from chemical action and excellent dielectric properties.

Araldite epoxy resins

Araldite is a registered trade name

Araldite epoxy resins are used

- for casting high grade solid insulation
- for impregnating, potting and sealing electrical windings and components
- for producing glass fibre laminates
- for producing patterns, models, jigs and tools
- as fillers for sheet metal work
- as protective coatings for metals, wood and ceramic surfaces
- for bonding metals, ceramics etc.

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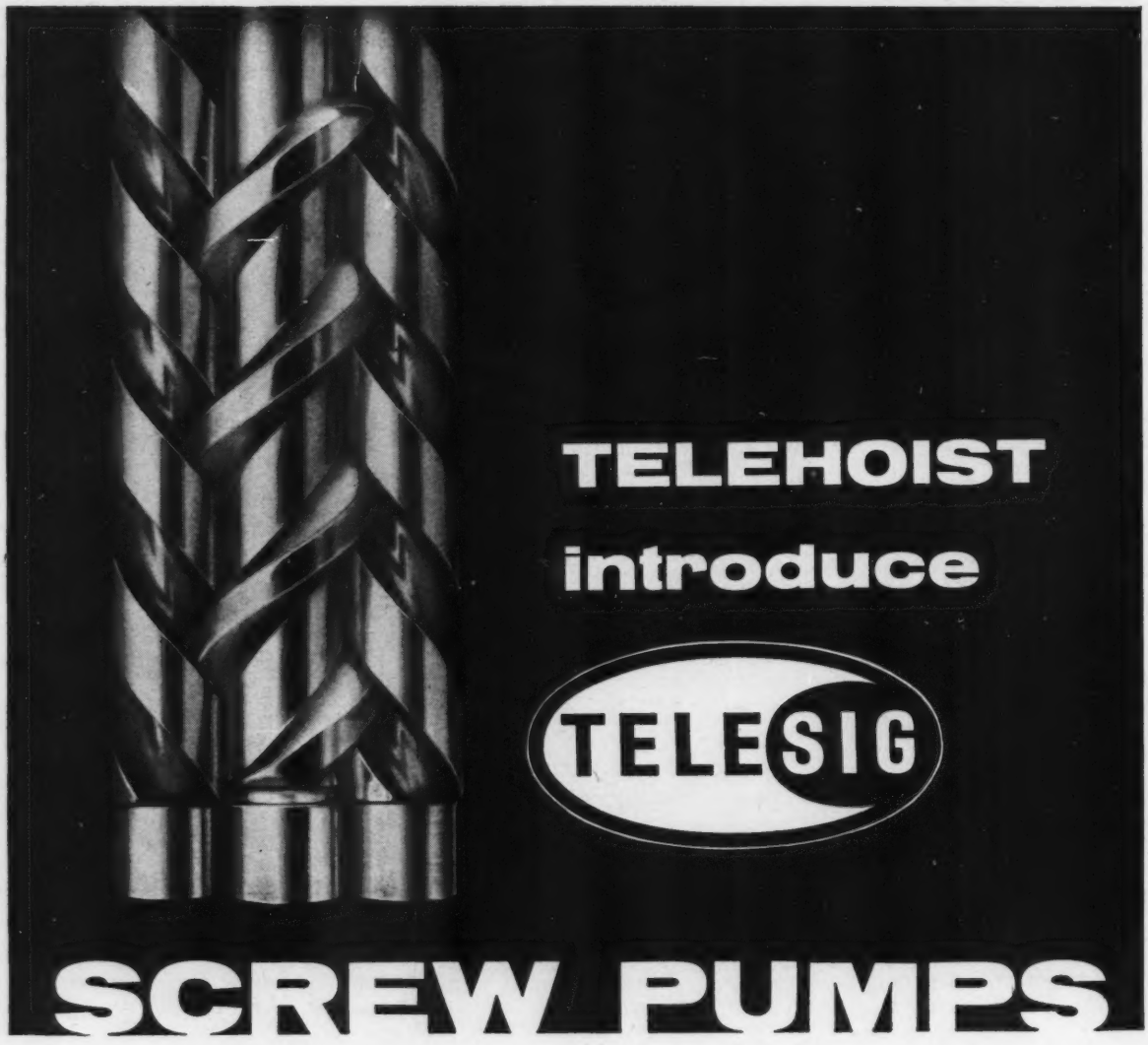
CIBA (A.R.L.) LIMITED *Duxford, Cambridge · Telephone: Sawston 2121*

AP 464



TELESIG Screw Pumps are positive displacement pumps. Simply constructed, they offer exceptional performance and long life. TELESIG pumps effect delivery by means of three parallel screws engaging each other, the power-driven central screw driving the two side screws. They may be run at high speed thereby reducing motor sizes and installation costs.

TELESIG Screw Pumps offer the following advantages:

- Self priming.
- Delivery free from pressure pulsation.
- High working speed — small size.
- Near-silent operation.
- Simple construction.
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- Long life.

TELESIG Screw Pumps are made in three basic ranges: for low pressures up to 300 psi, for medium pressure up to 1000 psi and for high pressures up to 2,500 psi. 42 sizes are available covering a wide range of capacities.

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Screw Pumps by Telehoist

TELESIG pumps and equipment are made by Telehoist under licence from the Swiss Industrial Company (SIG).

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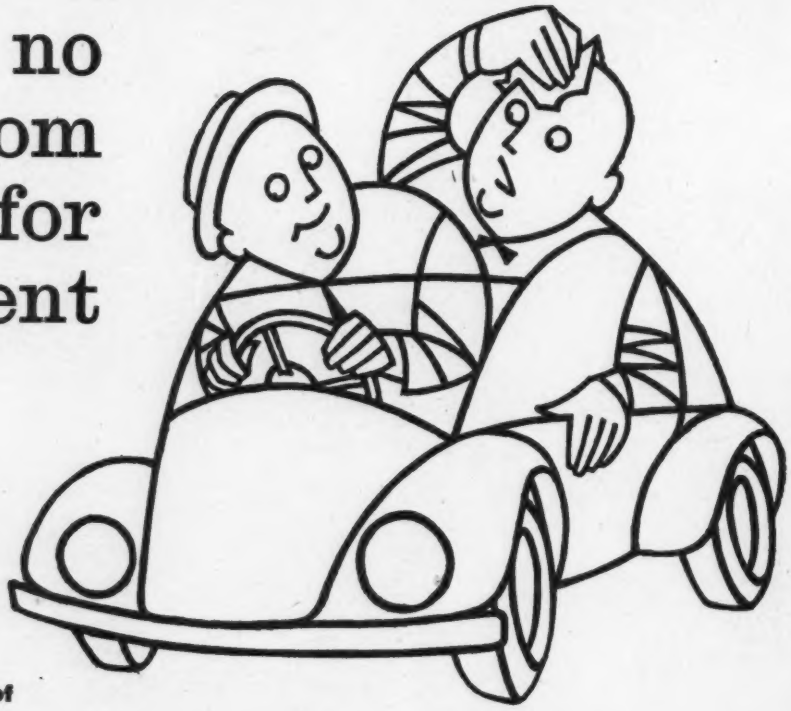
no room for argument



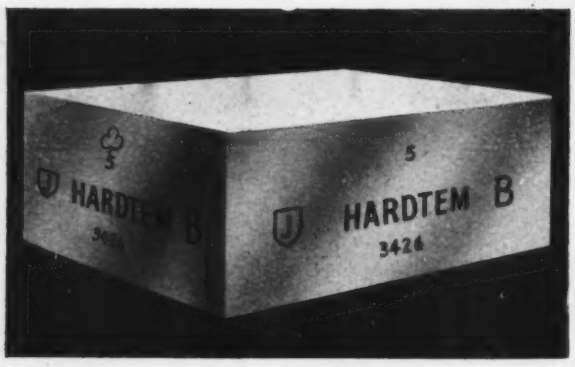
about the qualities of

HARDTEM DIE BLOCKS

Made from selected steel
under controlled conditions to give maximum production in drop forging.

They are available in four grades :—

Grade	Brinell Hardness	Application
Hardtem A	401 - 429	For small stampings with shallow impressions.
Hardtem BB	363 - 388	For most medium-sized stampings.
Hardtem CC	331 - 352	For larger stampings with impressions up to 5 inches deep.
Hardtem DD	293 - 321	For blocks with very large or deep impressions.



All grades can be supplied :—

1. Either annealed or hardened and tempered.
2. Either black or with one or more faces rough-machined.
3. Normally with lengthwise grain flow—but blocks with transverse grain flow can be supplied if desired.

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LIMITED
BRIGHTSIDE WORKS SHEFFIELD
A Member of the B.S.A. Group

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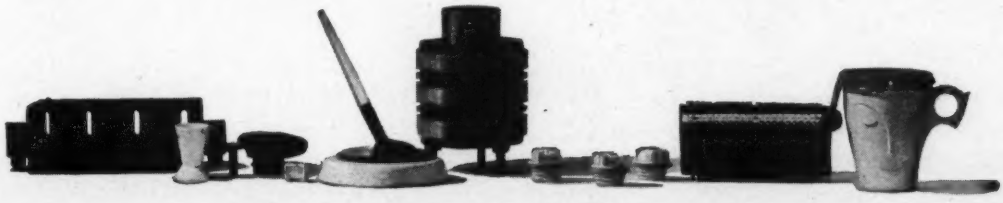
Streetly is equipped for the mass production of plastics mouldings to a high standard of accuracy and finish in all materials. The key lies largely in modern equipment, for all presses have automatic control of the moulding cycle to ensure consistency of cure and an unvarying standard in the moulded product.

Streetly has built its reputation on technical skill and reliability. The best measure of Streetly service is the status of its customers and the length of their mutually satisfactory associations.



STREETLY MOULDINGS

The Streetly Manufacturing Co., Ltd. *Streetly Works, Sutton Coldfield. Telephone : Streetly 2411*
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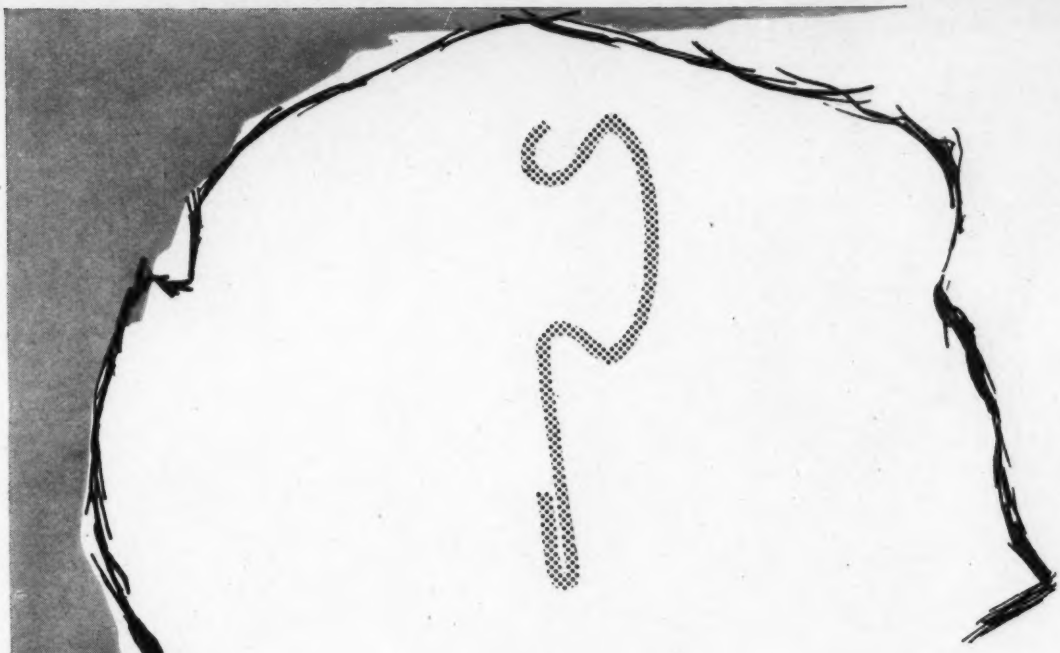

. . . *a section in mind?*

. . . you should contact Metsec. They're the people who provide the innumerable weird and wonderful cold rolled sections necessary for modern production. If your thoughts are confused on the shape you require or the possibility of producing it—let the Metsec team of experts help you. Write to them or return the coupon for general information.

Metal Sections Ltd

OLDBURY · BIRMINGHAM

Telephone: BROadwell 1541

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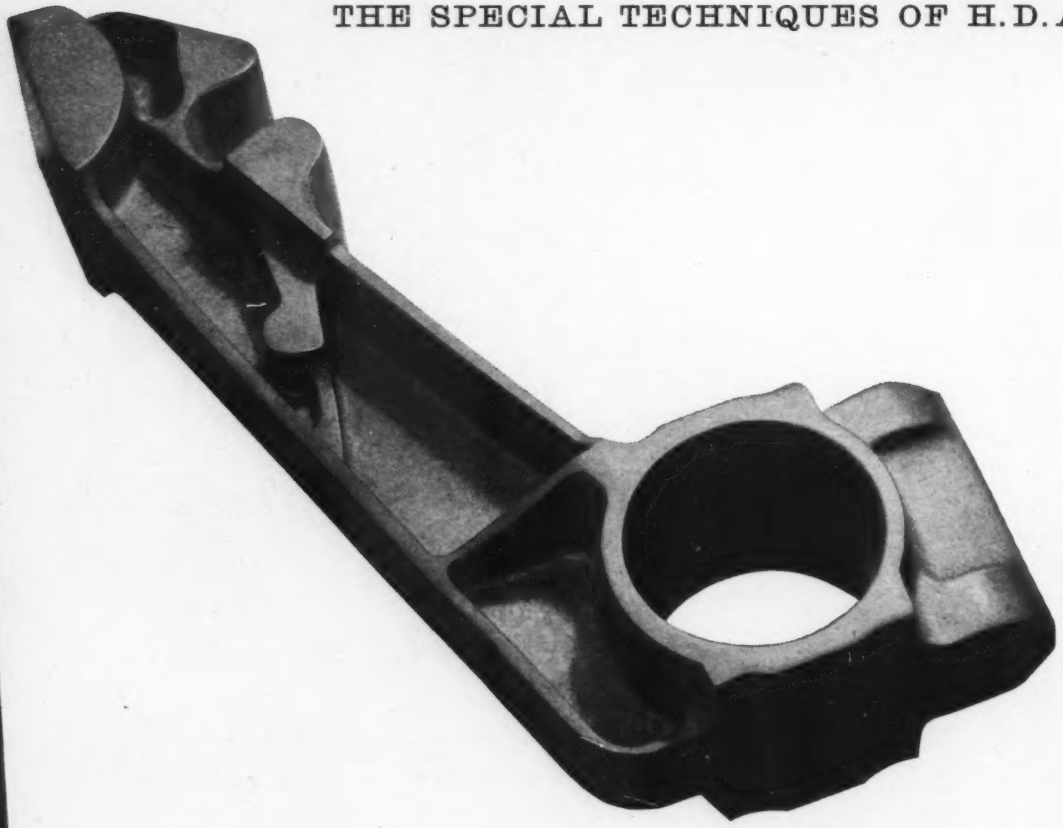
THE SPECIAL TECHNIQUES OF H.D.A.



Draftless Forgings. In forging, what is often accepted as impossible has been done by H. D. A.—extremely accurate draftless forging is one example of this. Developed by H. D. A. this technique produces forgings which have many advantages over those produced by conventional methods. **This saves time; this saves money; this saves effort. H. D. A. can do it.**

(Draftless forging in Hiduminium R.R.77) for H. C. Shepherd & Co. Ltd.

Hiduminium

makes the most of *Aluminium*

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when cables and tempers are frayed

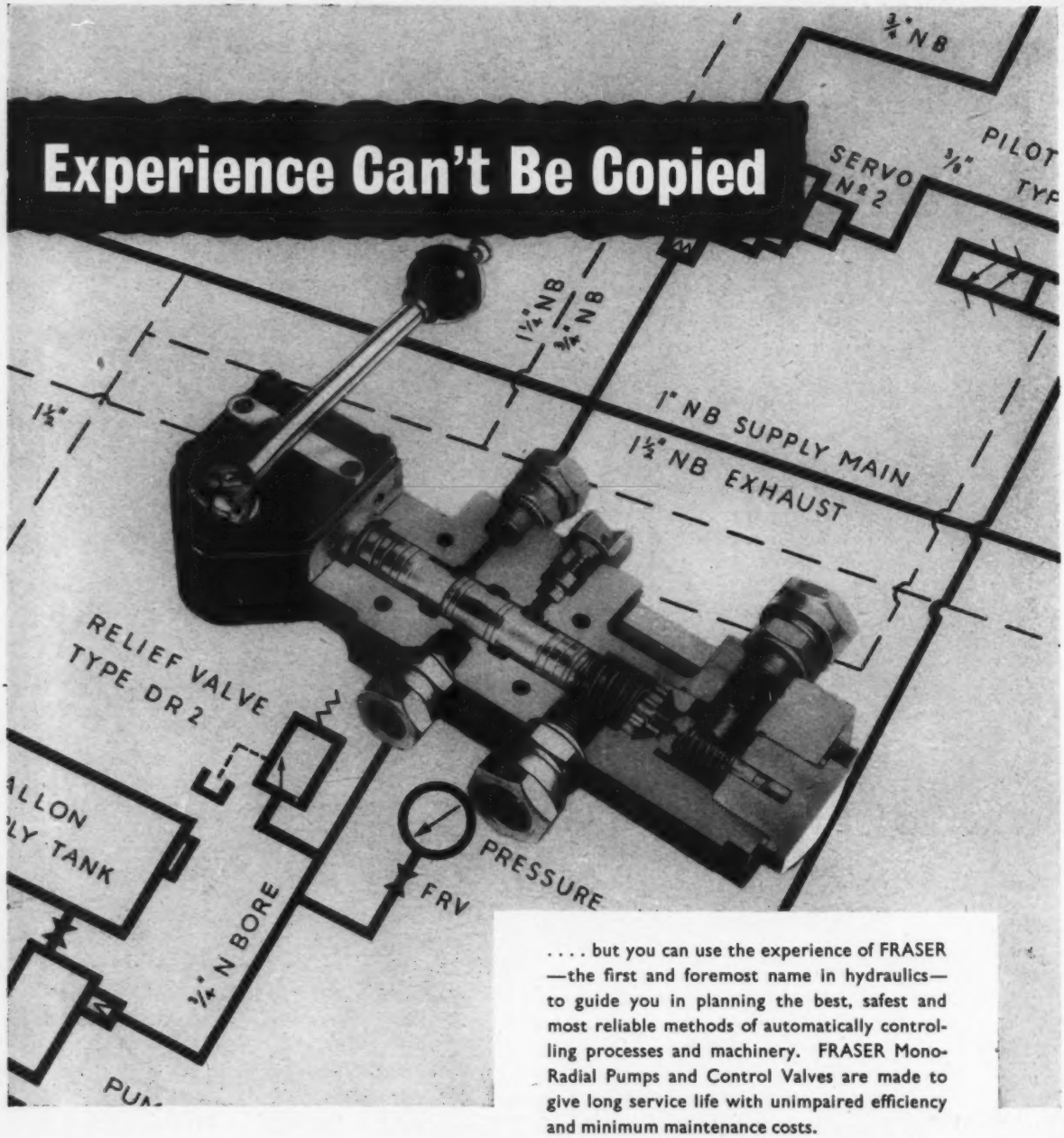
nothing is achieved by just sitting there, looking, in stony silence. Get hold of Hellermann Ltd – cable problems are right up their street.* Cable binding and marking sleeves are a favourite Hellermann topic.** *('Have you heard of this revolutionary new material, Helsyn-t?)* Sleeves and markers for *any* application are their stock-in-trade.

The Hellermann research laboratories test sleeves and markers daily, and a long list of impressive approvals bears witness to the excellence of the resulting products.

A first-class answer to your problems!

** and so are cable clips, wiring tools, crimped terminals, terminals blocks, plugs and sockets, and many other cable accessories.

HELLERMANN LTD* gatwick road, crawley, sussex



. . . . but you can use the experience of FRASER —the first and foremost name in hydraulics— to guide you in planning the best, safest and most reliable methods of automatically controlling processes and machinery. FRASER Mono-Radial Pumps and Control Valves are made to give long service life with unimpaired efficiency and minimum maintenance costs.

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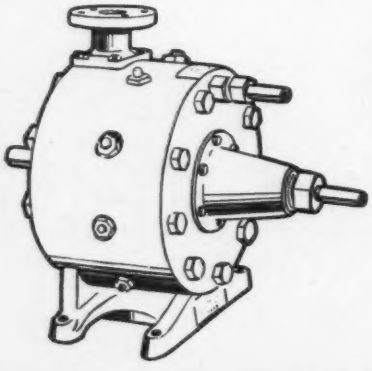

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The *best* constructional materials

COBEX Regd.

Rigid Vinyl Sheet

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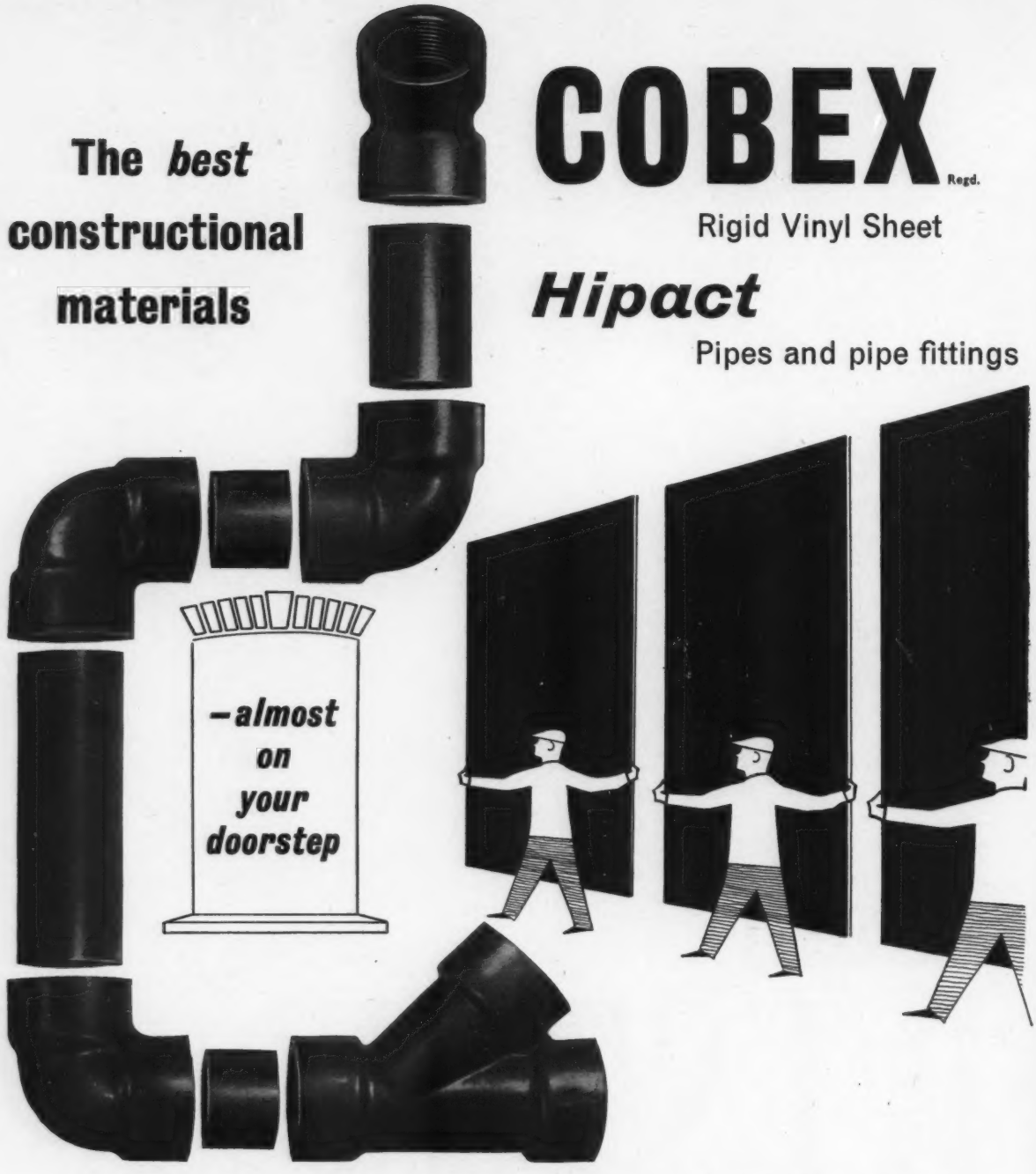

Chemical plant manufacturers need look no farther than BX Plastics for quick deliveries of everything likely to be required for corrosion-resistant constructions—*COBEX* rigid vinyl in large sheets of any thickness, Cobex/Velbex laminated sheets for linings, Hipact high-impact unplasticised PVC in pipes, fittings and valves in all standard sizes, manufactured by Extrudex Ltd.

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Tel: Gatley 6731

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BX PLASTICS LTD *A subsidiary of The British Xylonite Co. Ltd.*

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Beat corrosion!

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★ Manufacturers doing their own coating should use "BECKON" anti-corrosive paste which is highly resistant to TRICHLORETHYLENE.

Capacity available for dipping articles up to 8ft. in length × 18" × 60" in the form of Baskets, Work Trays etc. Used with our Primer 100% adhesion is assured.

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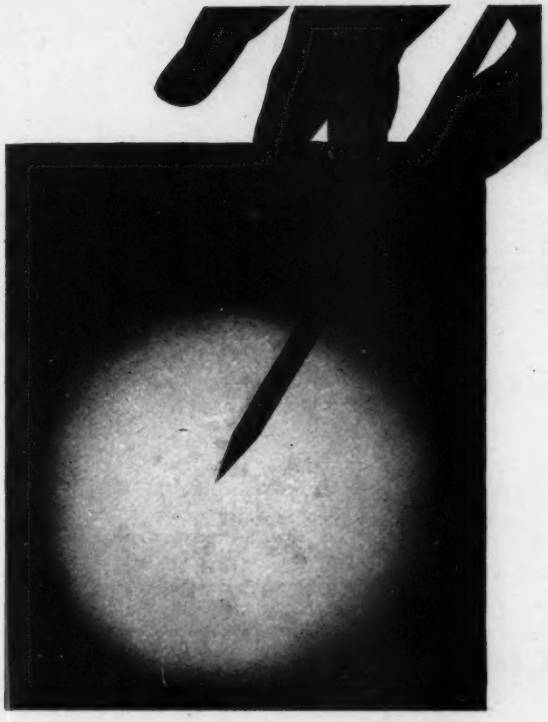

"probably the most potent instrument in the world"

For it gives most of man's thoughts and aspirations their first tangible form.

Consider a pencil, What an elegant little shaft it is! Basically simple, yet how indispensable to the most complex design! Notice how comfortably it sits in the fingers; for the polished cedar hexagon of a well-bred pencil with its many coats of gleaming lacquer, never forces itself upon one's consciousness, but, like a good servant, unobtrusively awaits one's bidding. Its smooth dense lead will give perfect reproduction of the finest lines, which nevertheless can easily be erased. The perfect point good humouredly stands heavy pressure and does not break, even when dropped. Pick up any degree from 6H to 2B (easily recognised by the coloured ends), they are true and never vary.

How fortunate is the draughtsman who finds all these attributes embodied in one pencil!

Perhaps that is why Rolls-Royce exclusively specify Koh-i-noor in their drawing offices.

KOH-I-NOOR

TO L. & C. HARDTMUTH (GREAT BRITAIN) LIMITED
KOH-I-NOOR FACTORY, CHARD, SOMERSET

Please send free samples of Koh-i-noor Draughtsman pencils for testing.

NAME OF COMPANY .....

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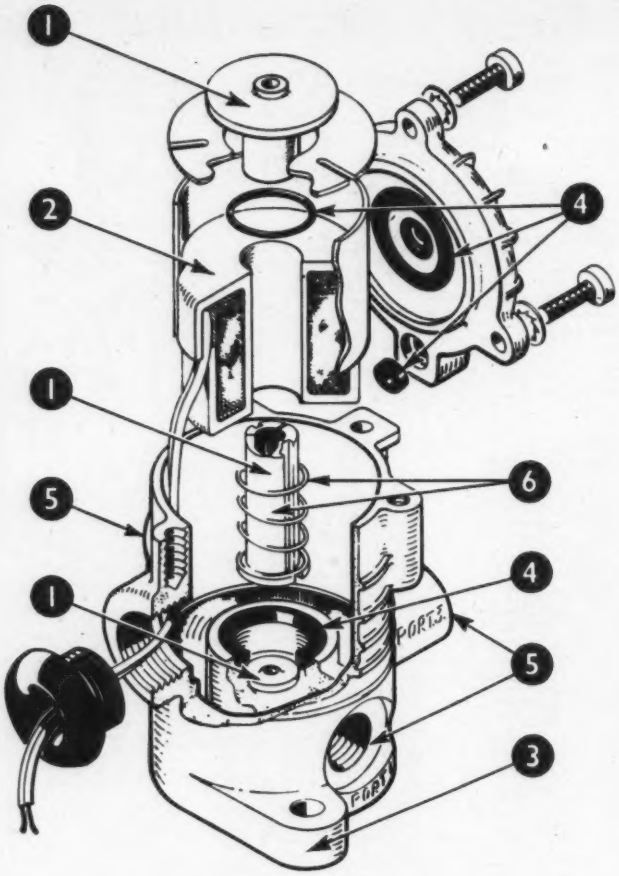
Detailed design and precision machining explain MAXAM quality and unfailing operation



Exploded for production engineers to appreciate its superior reliability, here is a pilot solenoid valve by MAXAM:-

1. ***Seats and Plunger*** — manufactured from plastic iron, heat-treated to provide maximum wear-resistance consistent with optimum electrical characteristics.
2. ***Encapsulated Coil*** — each one subjected to a 24-hour water immersion test before assembly. Available in a wide range of AC and DC voltages. Heat dissipation assisted by controlled medium passing through centre of coil.
3. ***Mounting Attachments*** — cast as an integral part of valve body.
4. ***Seals*** — of special synthetic rubber compound which resists the action of specified liquids and gases.
5. ***Operation*** — the valve can be arranged for two or three-way normally open, or normally closed operation.
6. ***Only 2 Moving Components*** — movement is confined to the plunger and spring, reducing wear (and consequently maintenance) to the minimum.

* ***Manifold Mounting*** — the valve body base can be drilled (drill-point recesses are provided) for mounting on a machined face.

* ***Compactness*** — overall height of the valve is only $3\frac{1}{16}$".

* ***Operating Pressures*** — range up to 250 p.s.i. depending on the valve arrangement and orifice size.

The design above is typical of the meticulous attention to detail and the superior care taken to ensure that MAXAM controls and air/hydraulic components shall work infallibly for as long as possible on the minimum upkeep cost. The whole assembly complies with the MAXAM emphasis on quality and reliability.

66% of current production from our machine shops is for companies whose designers — with experience of MAXAM product quality, performance and reliability — have planned their future flow production machines with MAXAM Controlled Fluid Power in mind!

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A company in the Holman Group which has branches, technical representatives and agents throughout the United Kingdom and the world

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For completely reliable operation with maximum economy — specify MAXAM ***Fluid Power Equipment*** MA 8

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*PERMANENT PROTECTION
*LOWER PRESSURE LOSS
*NON-COLLAPSIBLE

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answers your filtration problems

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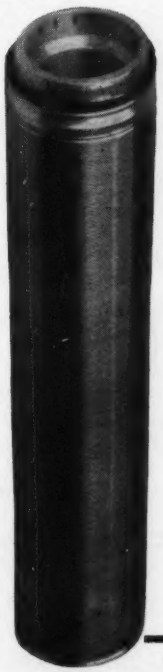
wire-wound filters are extremely robust and give continuous defined mesh protection throughout the life of the plant to which they are fitted. They combine high flows with the minimum pressure loss, ensuring the greatest degree of filtering efficiency.



AUTO-KLEAN LOLOS
are supplied in a range of single and multi-element filters for flows up to 40,000 gallons per hour, and as duplex filters or build-in filter elements.

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GIVES OFF-THE-SHELF DELIVERY

Here's great news for British Industry

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The Woodside Tooling Aids Catalogue detailing the complete range is available on request, and a staff of experienced engineers is ready to help users plan their production tooling from the outset.

WDS TRADE MARK

WDS TOOLING AIDS FOR INDUSTRY

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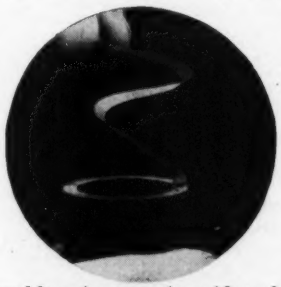
A BSC Company

Tecalemit Ribbon Filter Elements

Simple construction - Low cost - High flow rate - Easy to clean

The elements are formed of resin impregnated cellulose ribbon, wound helically and electrically polymerised and fused to form an open-ended cylinder. The standard range of diameters (in any length) covers most applications, and no other filtration material can so readily be adapted to individual requirements for filters, strainers or breathers.
Never before has such fine filtration been possible at such low cost and with such flexibility in use.



Innumerable microscopic orifices between the helically wound ribbons of the elements allow a very high flow rate, while retaining impurities on the outside or inside surfaces, according to direction of flow. Reverse flow readily cleans the elements, or they may be washed in petrol or paraffin.
Uses for Tecalemit Ribbon Filter Elements include:
carburettor inlet filters for small engines;
air intake filters for compressors and exhausters;
water separators for fuel and air lines;
filters and strainers for petrol, diesel, fuel and hydraulic oils, and oil burners, etc;
engine crankcase breathers and breathers for hydraulic tanks and systems.

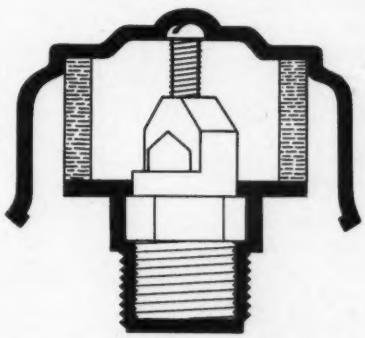
Tecalemit Ribbon Elements filter to maximum purity

Tecalemit Air Breather Filters

(incorporating Tecalemit Ribbon Filter Elements)

Cheapest—Most efficient—Cleanest to service

Of the standard types, two are breathers with screwed bodies, available in a range of British and American threads, and the third is a combined clip-on assembly of breather and filler cap, replacing the standard "pan-scrubber" type filter.



All are fitted with Tecalemit Ribbon Filter Elements, and are suitable for engine crankcases; air and vacuum brakes; hydraulic oil tanks and rams; gearboxes, pneumatic cylinders and servo mechanisms, etc.
Tecalemit Breathers fitted with ribbon elements act as ventilators to provide a free flow of clean air to hydraulic fluid, fuel and oil reservoirs. They compensate for changes in liquid level, temperature or altitude, as well as giving positive protection from airborne contamination to tanks, pumps, valves, cylinders and other components.

Tecalemit Breathers give pure air cheaply and efficiently

TECALEMIT – *the authority on filtration*

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EXTRA
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Cold Formed Sections

Cold formed sections, in mild steel, alloy steel, aluminium—almost any metal, and almost any shape, with extra depth up to 7½in and extra developed width up to 24ins. Minimum tool cost—none at all for standard angles, channels and lipped channels. Thickness from 26 gauge to ¼in. Any transportable length.

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It's as simple as that!

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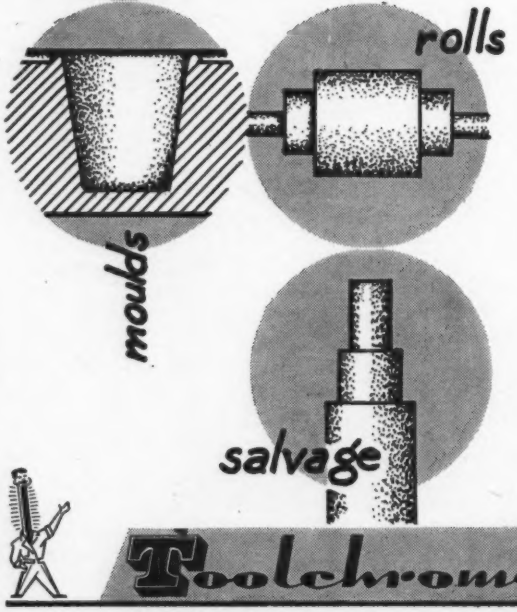

Toolchrome

TOOLCHROME LIMITED

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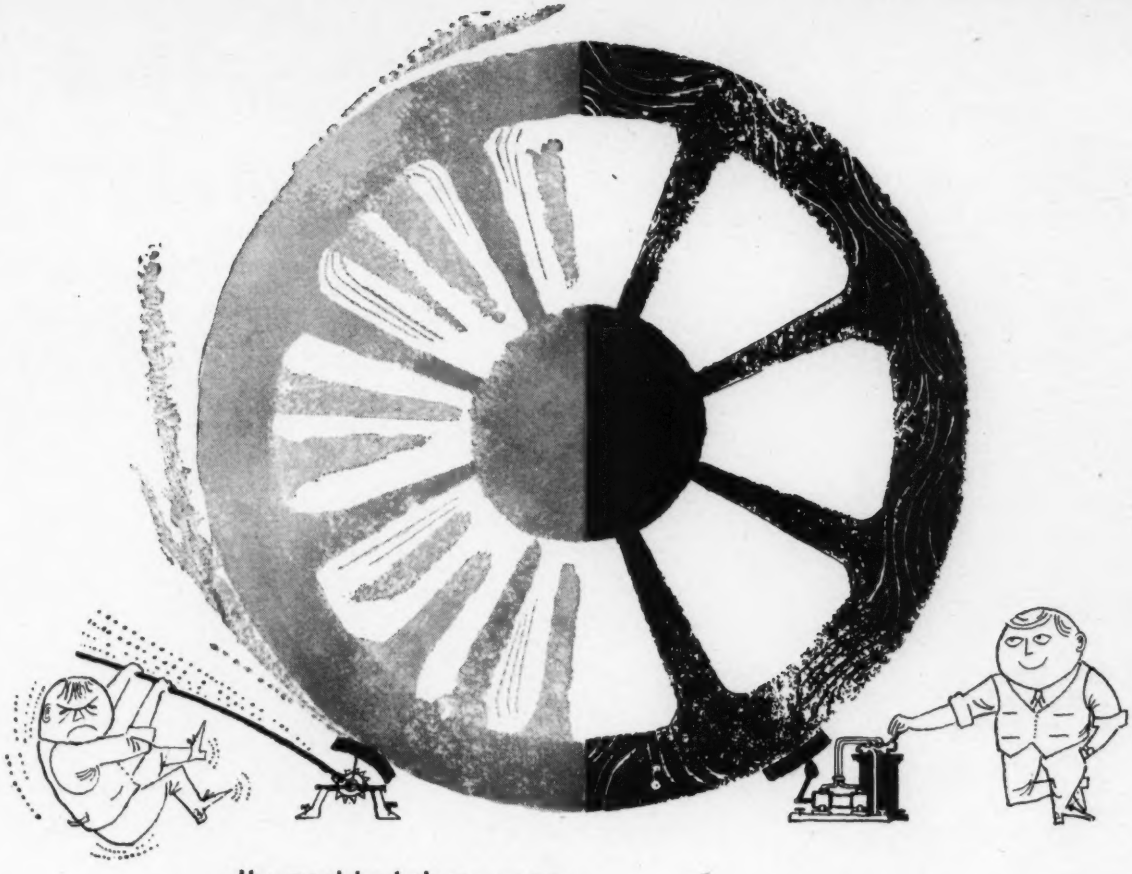


It used to take a man
3 minutes to stop this wheel

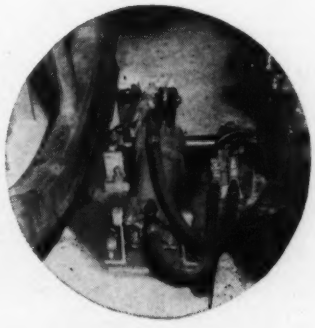
NOW IT TAKES HIM 15 SECONDS

The difference? **BALDWIN FLUID POWER**

Braking this heavy flywheel was a 3-minute job—until Baldwin took over. Now an air cylinder, hand-operated through a control valve, brings the wheel to rest in 15 seconds dead.

Baldwin tackle far more complex jobs than this—with proportionately greater savings in time and labour costs. Using electro-magnetic control valves of new design with air or low pressure hydraulic cylinders, a whole production process can be automated, simply, effectively and economically. Your existing air or oil supply will generally provide ample operating power.

And Baldwin tackle the whole job—process study, design and installation. We shall be very pleased to show you, without obligation, how Baldwin Fluid Power can speed your production and cut your costs. Write for Cat. EM 503, or better still, ask for one of our Technical Representatives to call. Do it now—call in Baldwin!



Fluid Power Division

Baldwin Industrial Controls

Baldwin Instrument Company Limited · Dartford · Kent

Telephone Dartford 2948 & 6411 · Cables & Telex Baldwin Dartford

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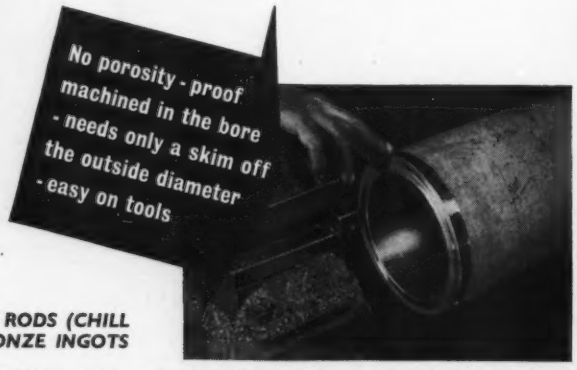
★ The inside diameter is supplied rough machined.
Standard 13" lengths



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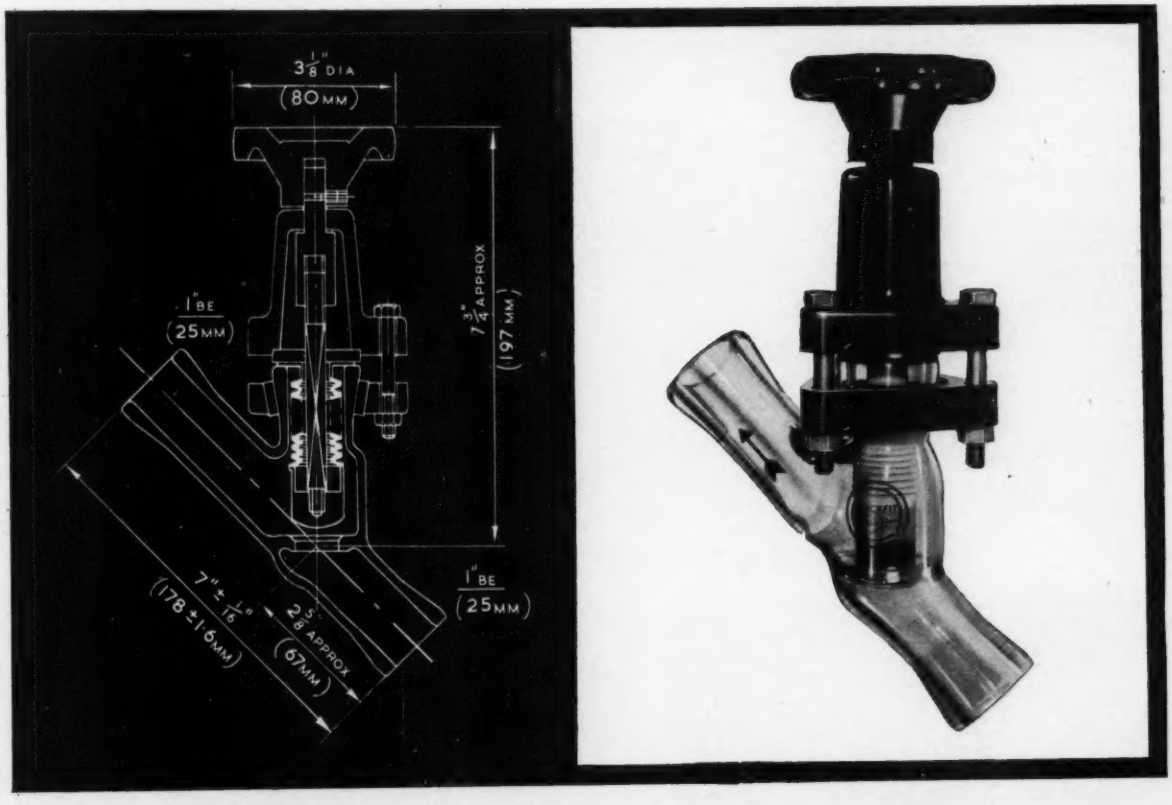

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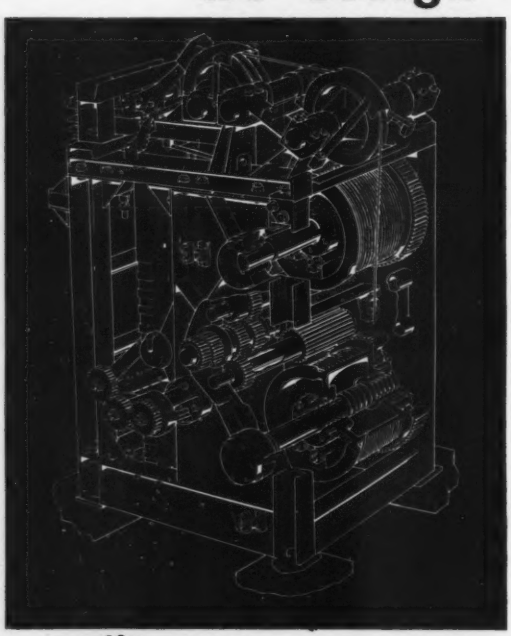

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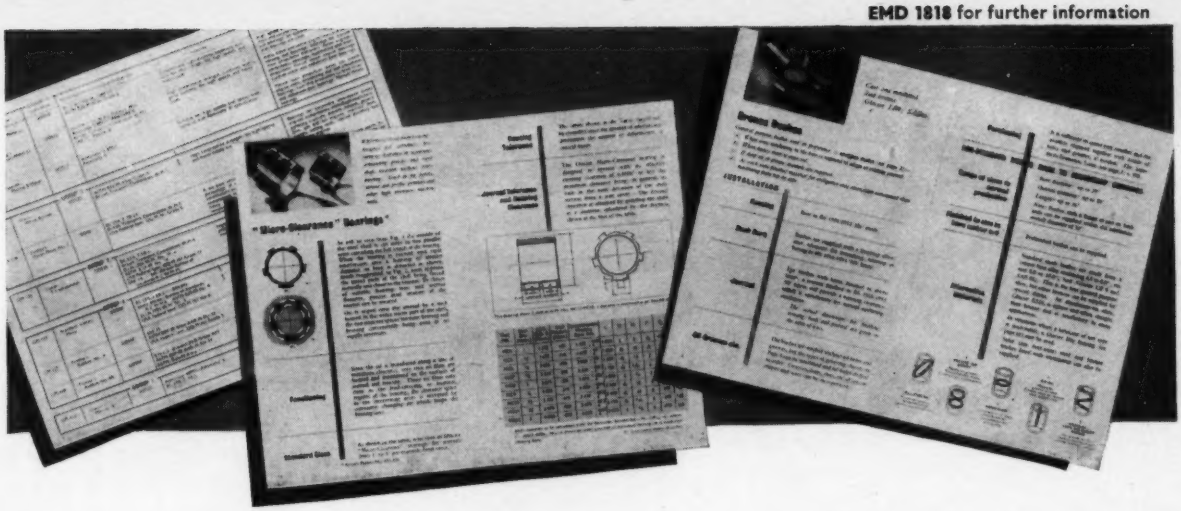

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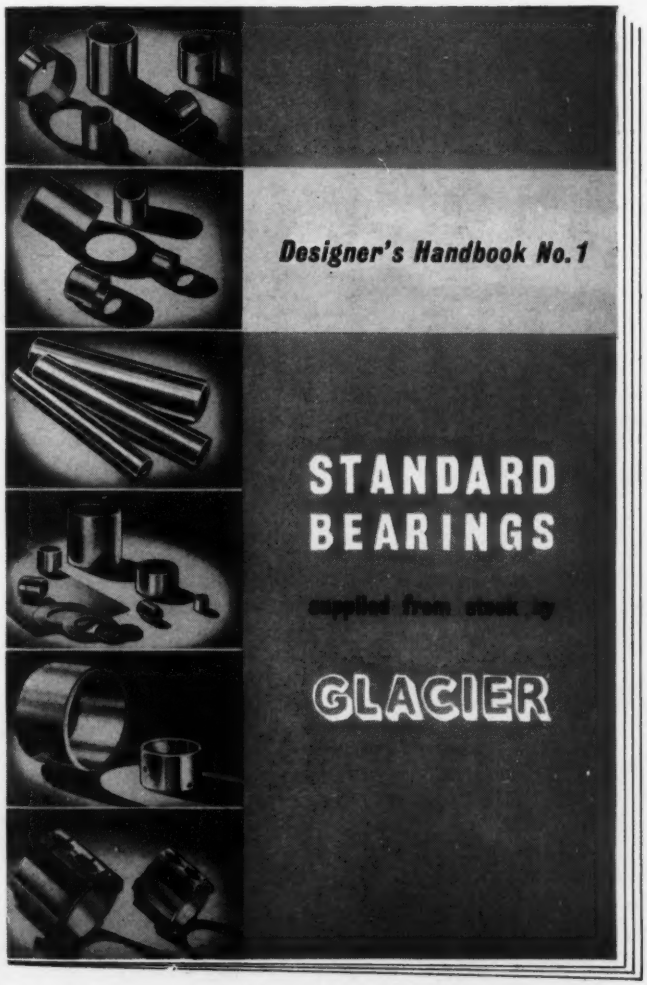

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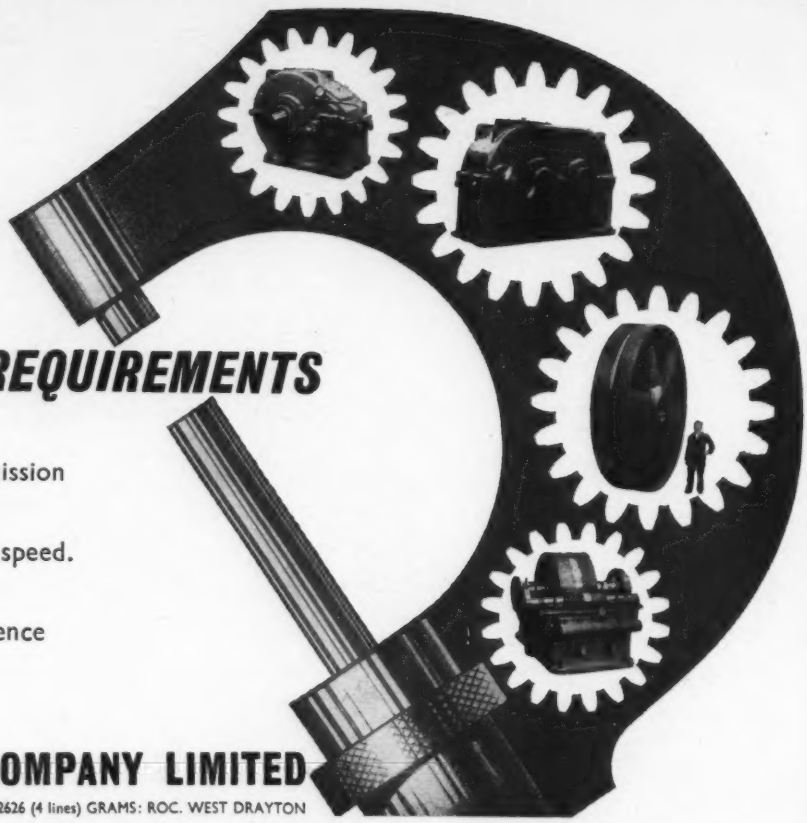

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CASTINGS	H. Morrogh, *British Cast Iron Research Association*
SEALS	Dr. E. T. Jagger, *Angus Oil Seals*
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PUMPS	J. O. S. McDonald (Editor) "*British Chemical Engineering*"
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RUBBER IN ENGINEERING	Dr. A. N. Gent, *British Rubber Producers' Research Association*
PLASTICS FOR HIGH TEMPERATURES	Dr. V. Yarsley, *Yarsley Research Laboratories Ltd*
DEVELOPMENTS IN FLUID POWER	D. Firth, *National Engineering Laboratory*
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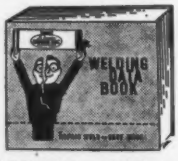

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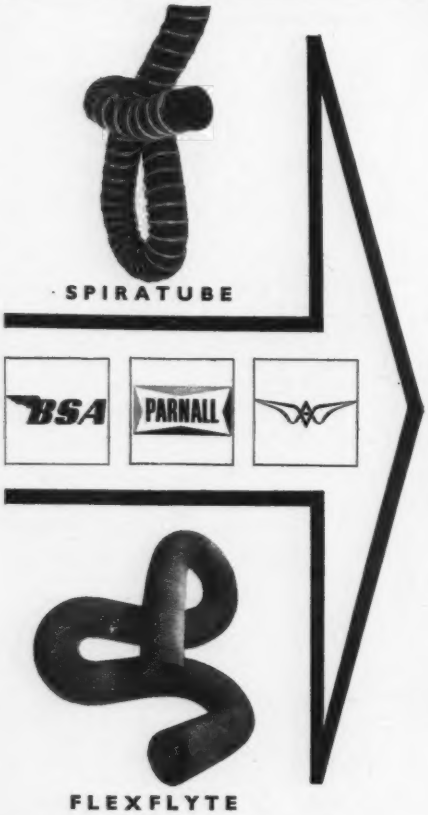

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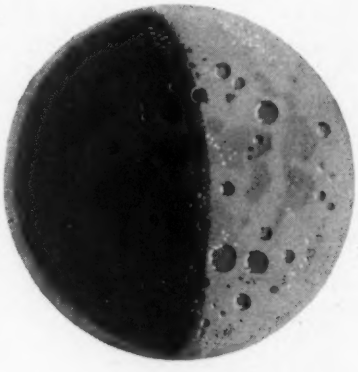

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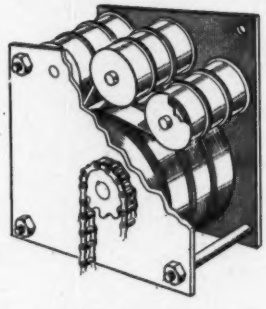

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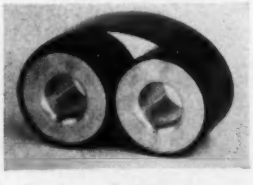

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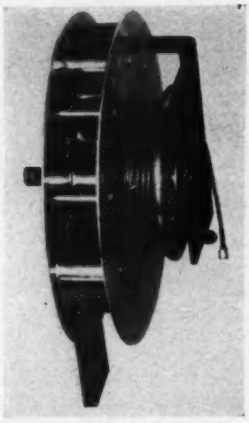

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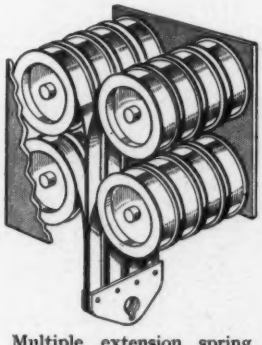

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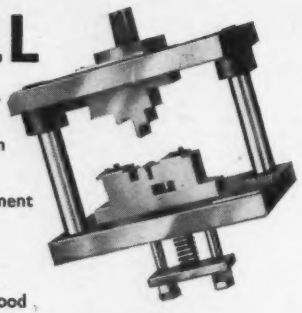

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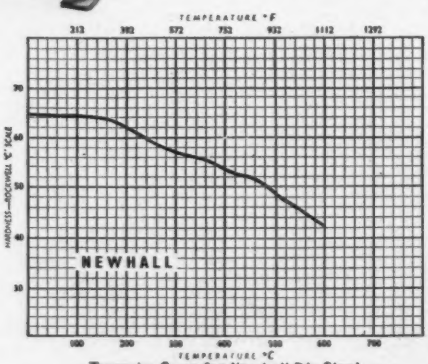

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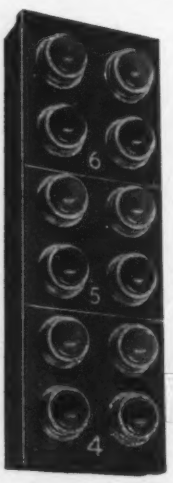

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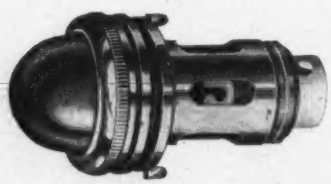

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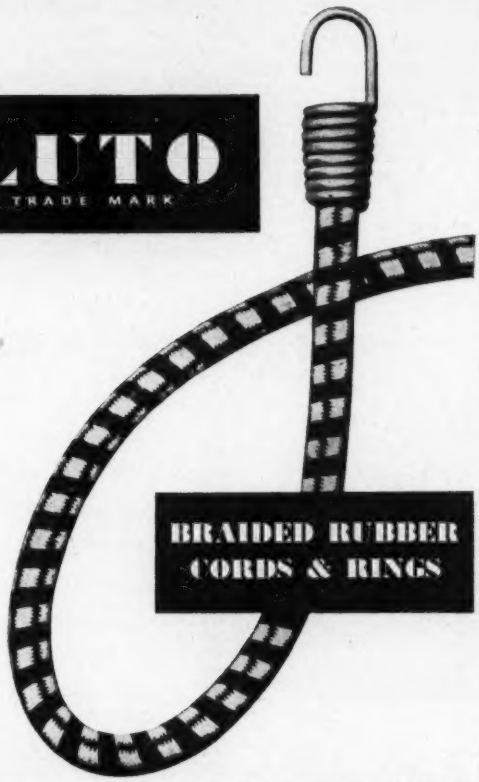

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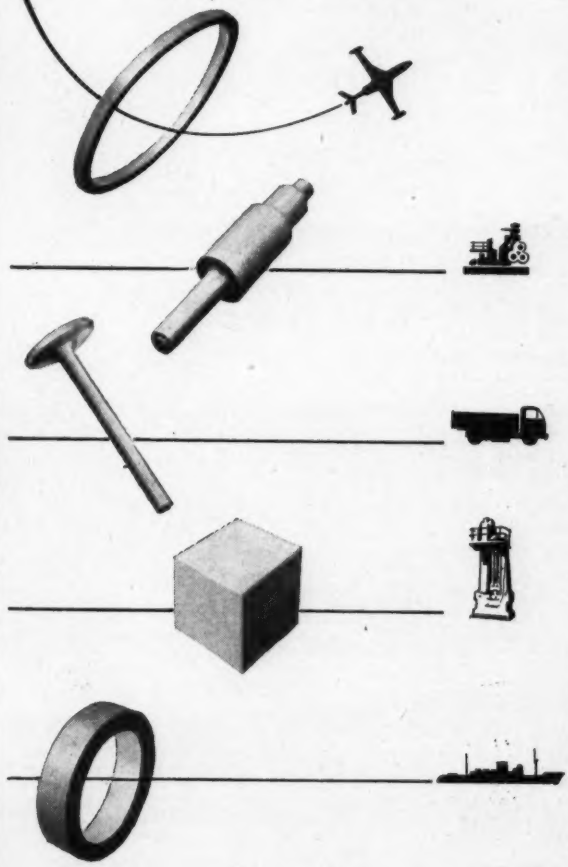

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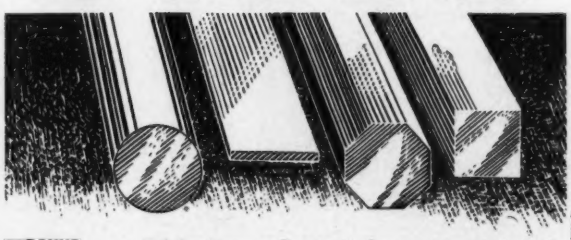

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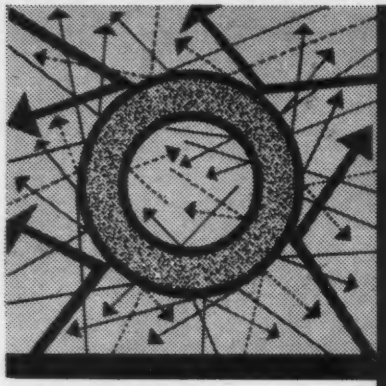

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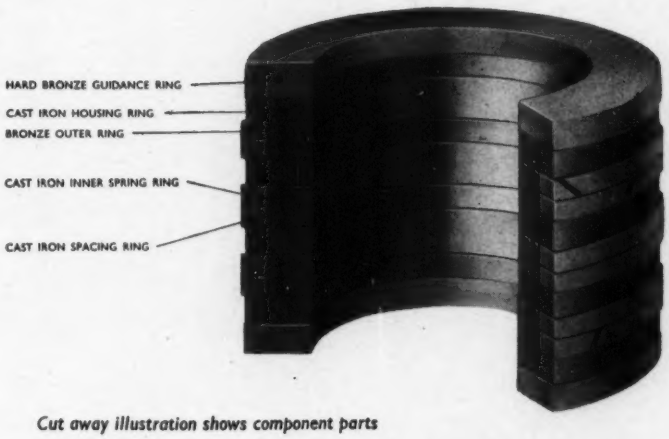

Cut away illustration shows component parts

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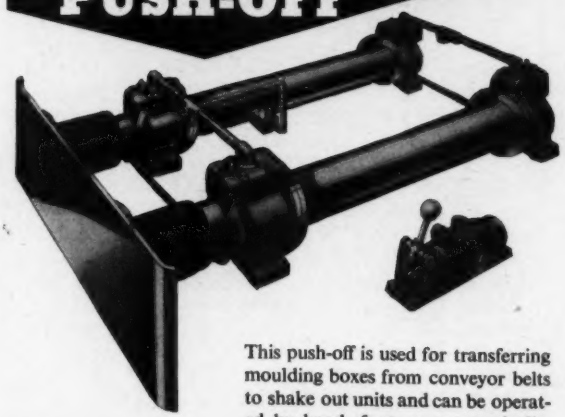

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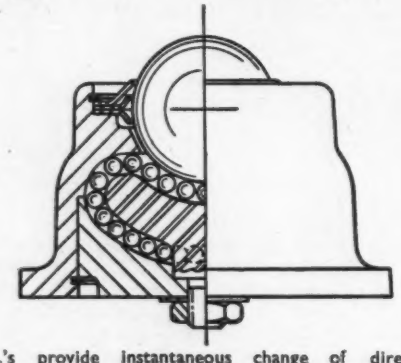

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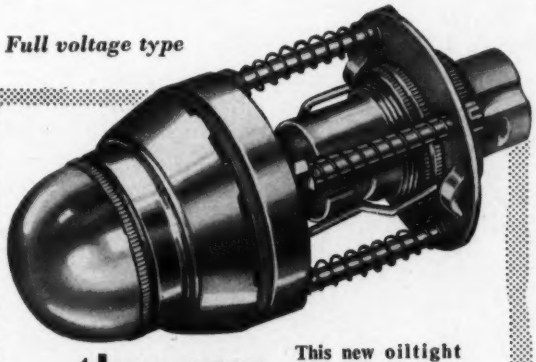

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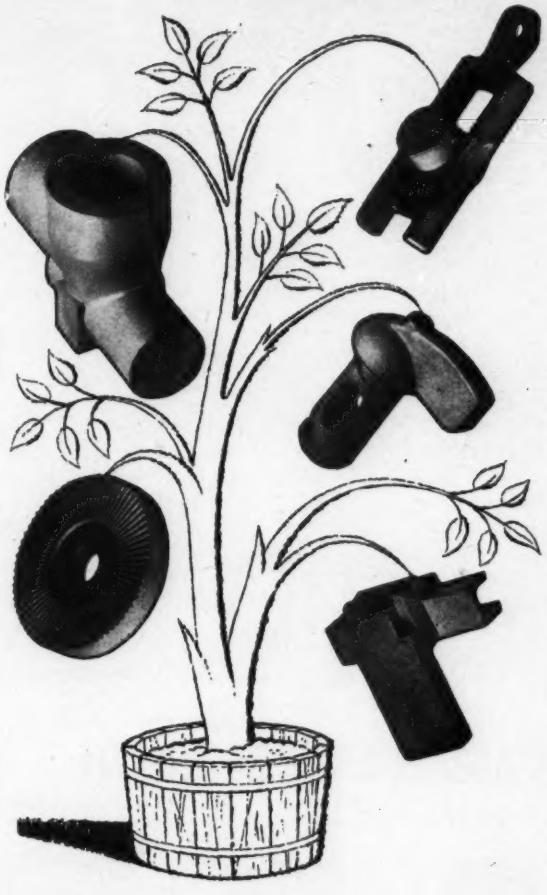

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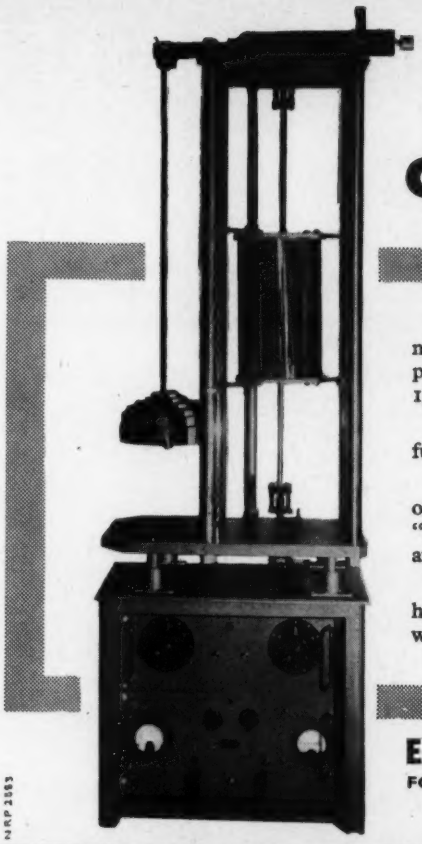

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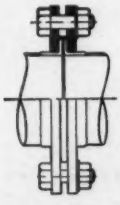

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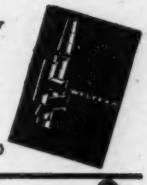

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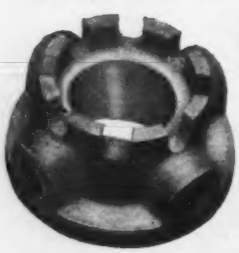

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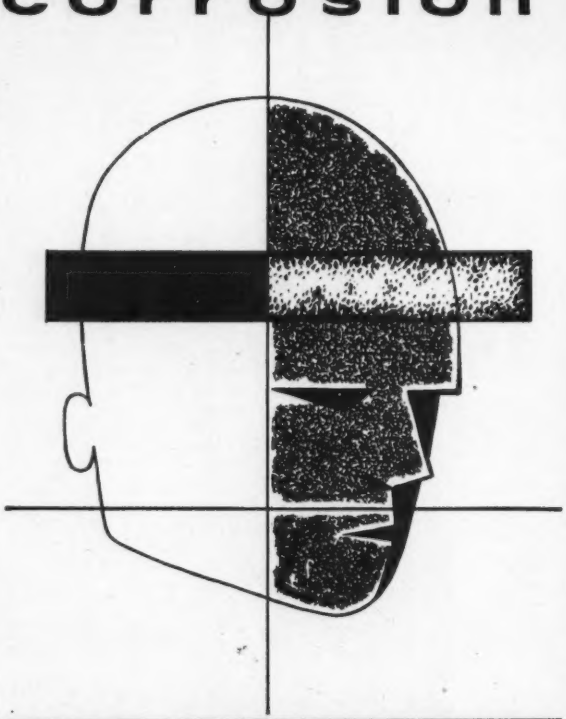

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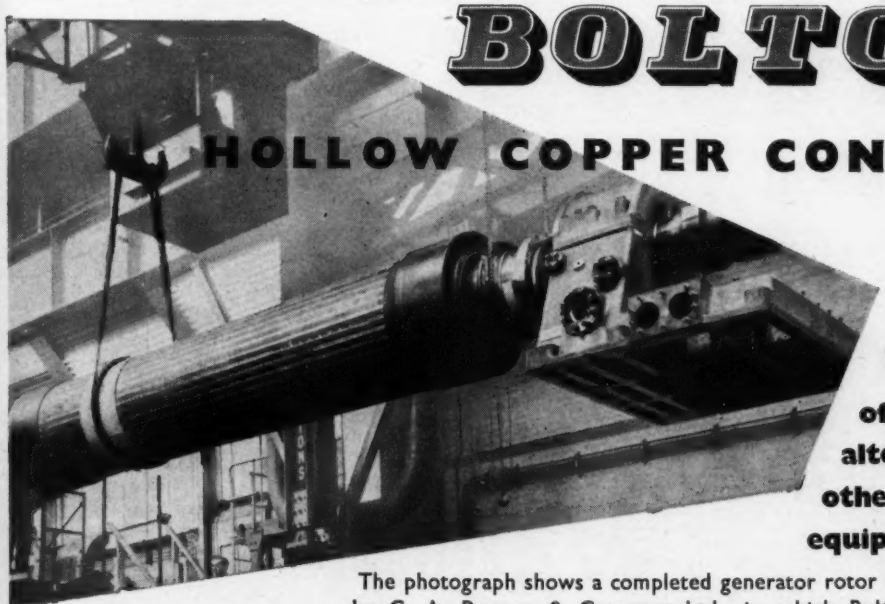

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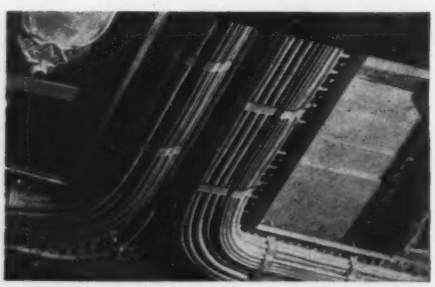

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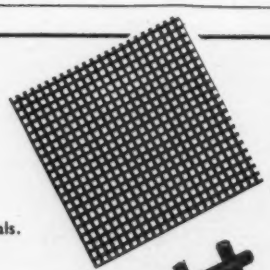

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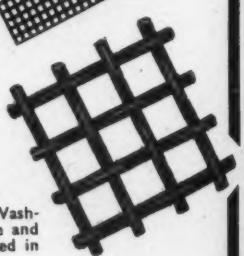

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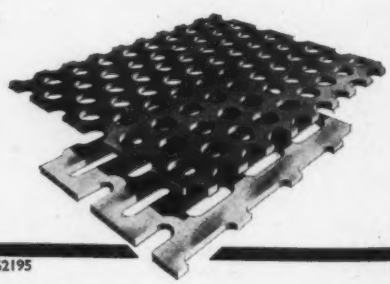

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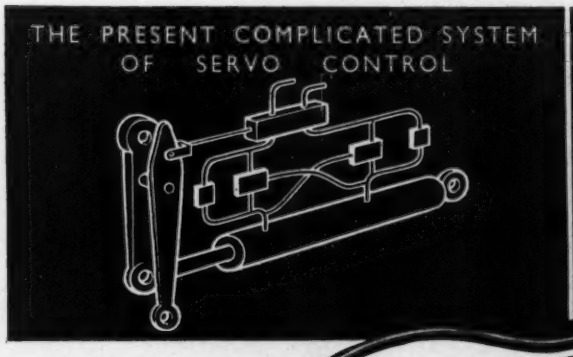

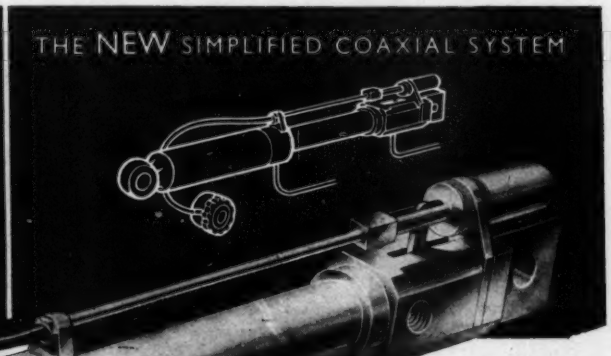

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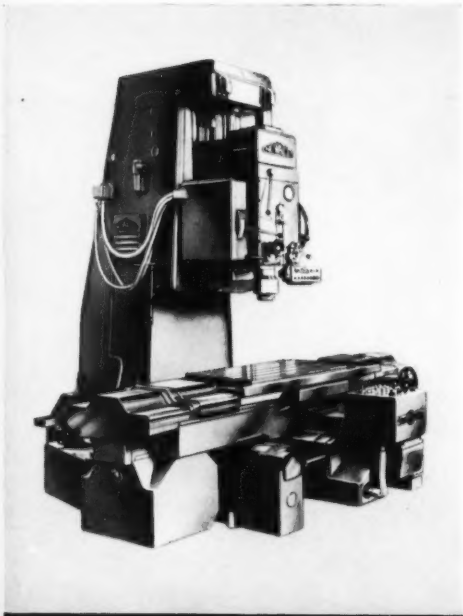

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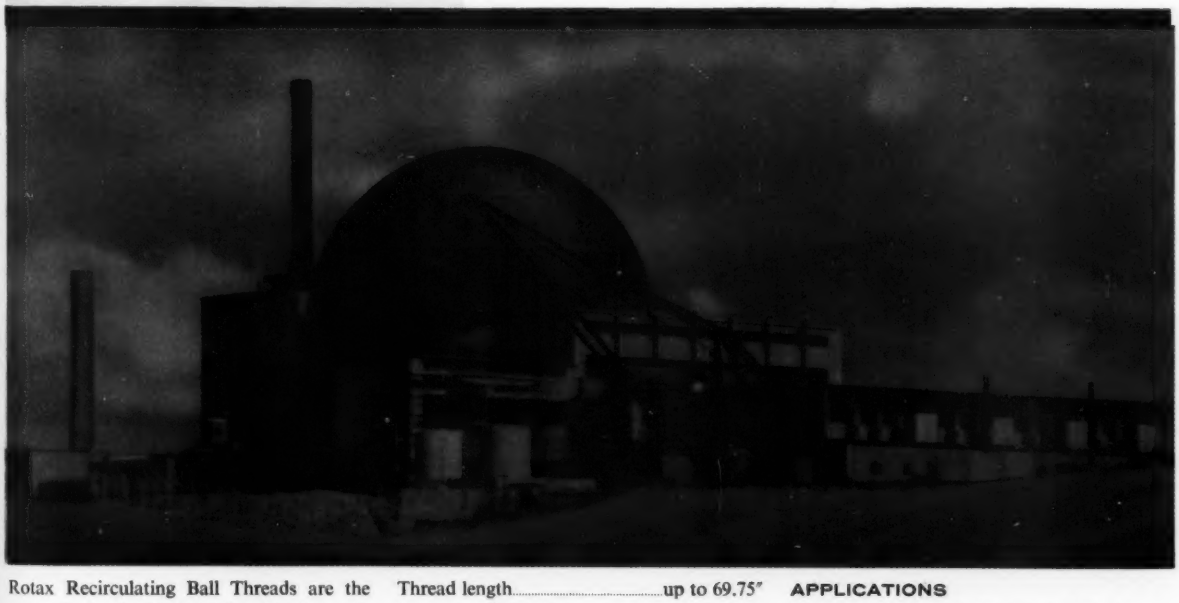

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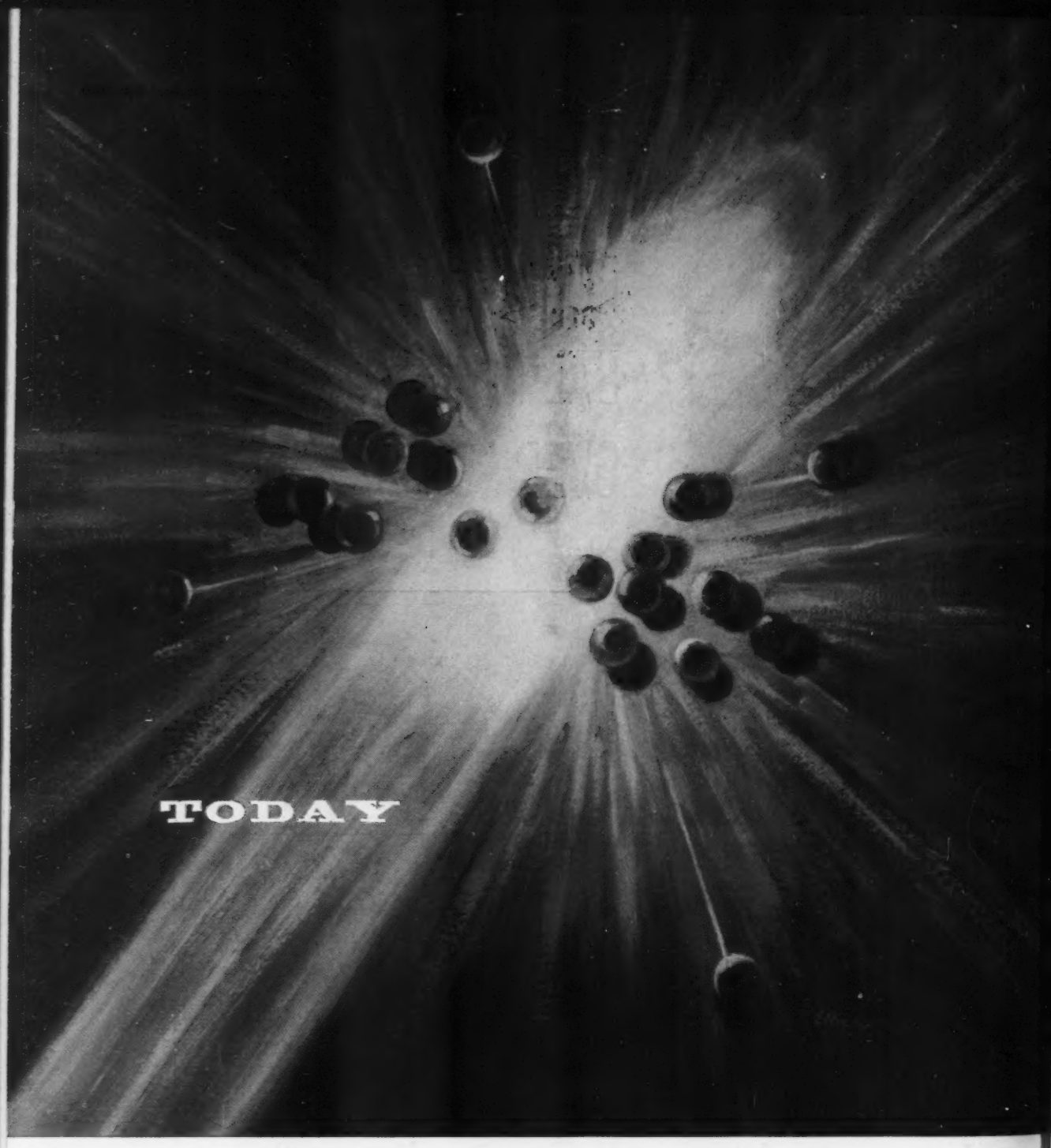

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